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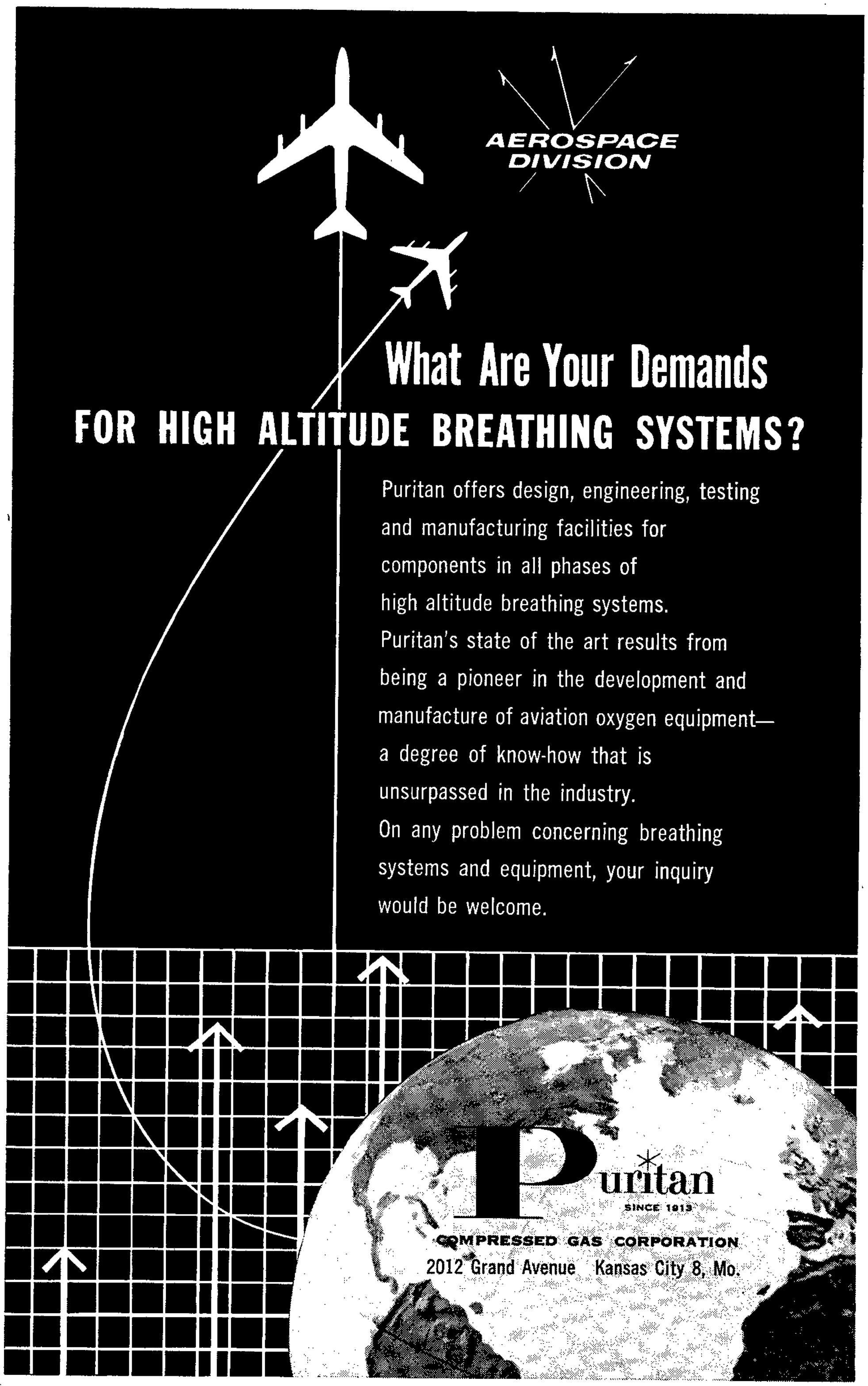
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VOLUME 31 NOVEMBER, 1960 NUMBER 11

Pathological Findings in Three Cases of Decompression Sickness

CAPTAIN RICHARD R. ROBIE, USAF, MC,
MAJOR F. WARREN LOVELL, USAF, MC, and
COLONEL FRANK M. TOWNSEND, USAF, MC

DEATH from decompression sickness due to high-altitude exposure is extremely rare. Adler[1] calculated the mortality to be seven fatalities in 1,000,000 exposures to altitude or simulated altitude. Masland[11] found six fatalities in a study of 470,000 training chamber runs, giving the approximate incidence of 1:80,000. Behnke[2] cited a mortality incidence of one fatality in 40,000 simulated altitude tests.

Fryer[9] has collected fifteen of the previously known fatal cases of decompression sickness. These, plus a recently reported case by Odland,[13] give a total of sixteen fatal cases of which we are aware.

This article will present three of the most recent cases of decompression sickness accessioned by the Armed Forces Institute of Pathology. Emphasis is placed on the pathologic findings, or the lack of demonstrable pathologic findings, in this disease. No attempt is made to review the clinical syndrome because a recent review article by Pfrommer[14] does so.

From the Aerospace Pathology Branch, Armed Forces Institute of Pathology, Washington, D. C.

Presented at the Aerospace Medical Association meeting in Miami, Florida, May 10, 1960.

CASE REPORTS

Case 1.—This thirty-six-year-old Air Force Major, who was 73 inches in height and weighed 235 pounds, was an experienced pilot, having accumulated 3,565 hours of flying time, 251 of these in jets.

Two hours prior to an evening take-off, the pilot had a cocktail and a fatty meal. Preflight checks were normal, with the exception of complaint of discomfort from survival gear and the fact that he could not sit upright, as his P-4 helmet struck the canopy.

One hundred per cent oxygen was used during the climb to 5,000 feet. Mission altitude was 29,000 feet ambient, and cabin altitude was repeatedly reported as 22,000 feet. Approximately thirty minutes after take-off, the patient coughed violently and complained of chest pain. Five minutes later he lost consciousness. The mission was immediately aborted, and the aircraft was landed by the navigator, who was not a pilot. The landing gear collapsed crossing an

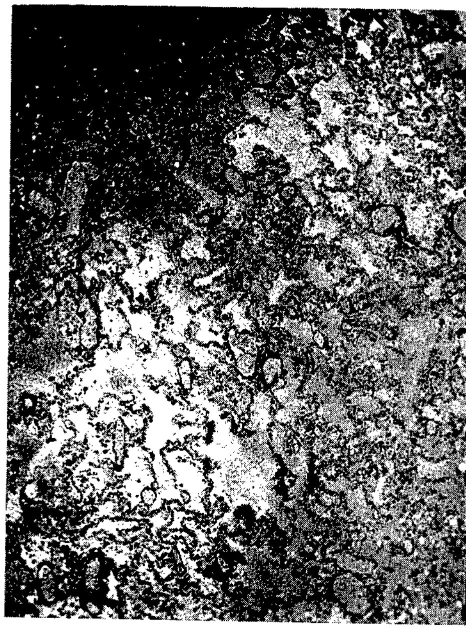

Fig. 1. Pulmonary congestion and edema. Hematoxylin and eosin stain. ×40. AFIP Neg. No. 60-1832.

Fig. 2. Pulmonary fat embolus. Oil red O stain. ×175. AFIP Neg. No. 60-1831.

overrun, but neither occupant was injured by the landing.

Physical Examination.—When first seen, the patient was moribund. He was somewhat revived by an injection of caffeine sodium benzoate and responded to stimuli but was confused and disoriented. He was noted to look older than his stated age and was heavy set. There was moderate cyanosis. The pupils were dilated and equal, with good corneal and eyelid reflexes. The skin was dusky and sweating. There was no distention of the neck veins. There were a few scattered wheezes in the lungs. The heart sounds were of fair quality, with no murmurs. The pulse was 87 and regular. Blood pressure was 96/60. The neurologic examination showed flaccid extremities bilaterally and complete absence of deep tendon reflexes.

Laboratory Findings.—ECG tracing was interpreted as incomplete right bundle branch block and nonspecific ST segment changes.

Hospital Course.—Shortly after admission the patient became unconscious, and the blood pressure and pulse were not obtainable. Intravenous fluids and Levophed raised the blood pressure, but despite this the patient remained unconscious, and his condition gradually deteriorated. The blood pressure dropped, the pulse became feeble, and the cyanosis and mottling of the skin grew worse. Gradually, the patient developed Cheyne-Stokes respiration and a fever of 103°. He died thirteen hours after onset of symptoms.

*Postmortem Examination**

Gross.—The autopsy was begun twenty-two hours after death. There was cyanosis of the head and neck. The panniculus measured 5 cm. in thickness. There was no pneumothorax. The pleural spaces contained 200 cc. and 150 cc. of serous yellow fluid, respectively.

The heart weighed 460 gm. No air bub-

*Prosectors: Major C. W. Delia, MC, USA and Captain G. F. Huck, MC, USA.

bles were demonstrated in the left auricle under water. The coronary arteries showed very minimal atherosclerosis. The foramen ovale was anatomically patent but functionally closed.

The lungs weighed 1,650 gm. Crepitation was decreased, and a cut section showed a wet, congested lung with hyperemia of the bronchial mucosa.

The spleen weighed 350 gm. Cut surface showed a soft, reddish parenchyma. The liver weighed 2,800 gm. Cut section showed a light brown color with normal lobular pattern. No abnormalities were observed in the gastrointestinal tract or pancreas.

The kidneys weighed 160 and 175 gm. The left ureteropelvic junction was slightly narrowed, and there was a moderate hydronephrosis on the left.

The brain weighed 1,800 gm. There was a moderate pressure cone over the inferior surface of the cerebellum.

Microscopic: Viscera.—The lungs showed marked congestion (Fig. 1), and the majority of the alveoli were filled with edema fluid. Frozen sections stained with oil red O (ORO) for fat showed a minimal number of fat emboli in the small pulmonary arteries (Fig. 2).

The heart showed congestion and severe interstitial edema with a focal increase in interstitial cells, chiefly neutrophils with a few mast cells. Focally, the myofibrils showed a slight tinctorial difference in staining and slight granularity of the cytoplasm.

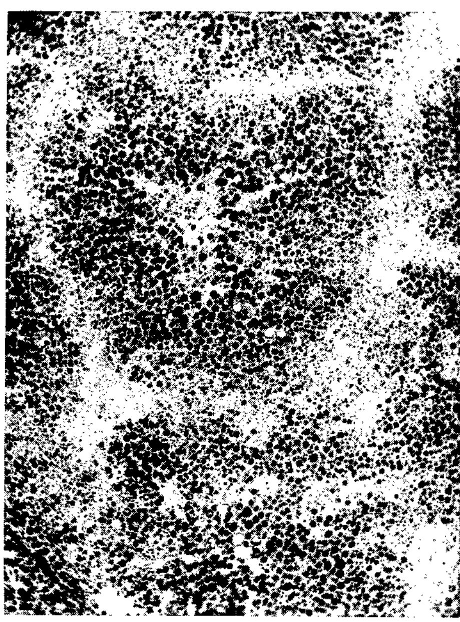

Fig. 3. Fatty metamorphosis of liver, severe. Oil red O stain. ×25. AFIP Neg. No. 60-1833.

Fig. 4. Ischemic infarct in brain. Lillie myelin stain. ×85. AFIP Neg. No. 60-1835.

The spleen was moderately congested.

The liver showed marked fatty metamorphosis (Fig. 3) throughout a normal lobular architecture.

The pancreas showed almost complete autolysis of the pancreatic parenchyma.

The kidneys exhibited congestion and pronounced autolytic change, which made a diagnosis based on cellular detail tenuous. The glomeruli were normal in appearance except for an occasional hyalinized glomerulus in the left kidney. ORO stains showed an occasional fat embolus in the glomeruli.

Brain.—The sections showed evidence of moderate cerebral edema throughout the entire brain. Vascular engorgment of both the pial and cerebral blood vessels, including the capillaries, was very prominent.

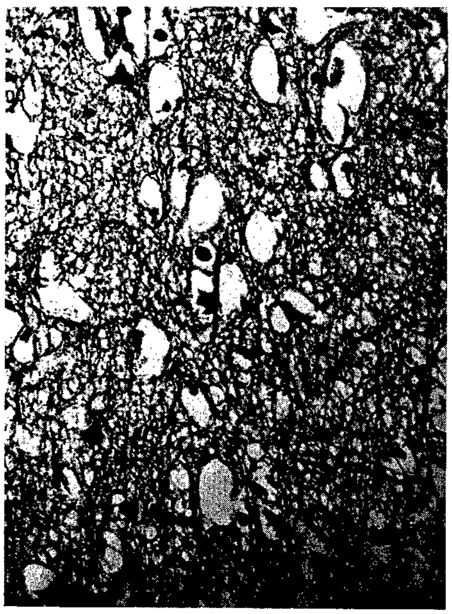

Fig. 5. Ischemic infarct in brain. PTAH stain. ×235. AFIP Neg. No. 60-1836.

There was occasional minimal perivascular hemorrhage. The neurons of the cerebral cortex showed mild pyknosis, satellitosis and minimal neuronophagia. Some of these changes may have been the result of autolysis. Special Lillie and PTAH stains showed areas of ischemic necrosis (Fig. 4) which were both focal and geographic and were located near the junction of the white and gray matter. These areas were rather sharply demarcated and were characterized by a porous, spongy appearance. The cells showed hyperchromatism and marked pyknosis, and some had completely faded away (Fig. 5). There was marked autolysis in the granular layer of the cerebellum.

Case 2.—This thirty-two-year-old white chief petty officer was flying as a crew member in an unpressurized A3D at an altitude of 33,000 feet. Approximately one and one-half hours after take-off, he developed moderately severe pain in the left knee and thigh. This pain warranted limiting his motion, but he did not notify the pilot. The pain slowly subsided, and approximately thirty minutes before landing the patient felt weak and light headed. He developed a generalized throbbing headache and began to sweat profusely. Nausea and extreme suprapubic pain followed. After stepping out of the aircraft, he nearly fainted and was taken to the dispensary. At that time he was pale, slightly cyanotic, very apprehensive, and hyperventilating. He denied chest pain but felt a tight band around his chest and seemed dyspneic. The abdominal pain persisted and the patient was somewhat relieved by lying on either side. He was mentally oriented.

Physical Examination.—The patient was obese and looked older than his stated age. He measured 65 inches in height and weighed 241 pounds.

The blood pressure was 90/40, pulse 100, and respirations 26. Temperature was 97.8°

The skin was cold, moist, and cyanotic. The pupils were round and equal. No abnormalities were observed in the fundi. There were moist râles in the lungs as well as expiratory wheezes and a prolonged expiratory phase, mainly in the posterior aspect of the base of the left lung. There was a tachycardia with regular rhythm. The heart tones were muffled and distant.

The abdomen was obese, soft, and somewhat tender in the lower portion. Bowel sounds were present. The extremities were obese and cyanotic. The left calf was slightly tender.

The neurologic examination showed only some facial weakness and the patient demonstrated difficulty in swallowing.

Hospital Course.—The patient was initially given Aramine and intravenous fluids with Levophed. The blood pressure improved but never rose above 80/40, and the pulse slowed to 50 a minute. The lung sounds improved.

One hour following this initial improvement, the blood pressure fell and remained unobtainable except occasionally by palpation. The pulmonary edema recurred. After a coughing paroxysm, he became unresponsive, then developed a focal motor seizure involving the left arm and hand, after which he again regained consciousness.

Terminally, the patient went into ventricular fibrillation and, despite cardiac massage, died nine hours after the onset of symptoms.

*Postmortem Examination**

Gross.—The autopsy was begun fifteen hours after death. There was cyanosis of the face, lips, neck, upper thorax, and lower extremities. The conjunctiva and gingiva showed punctate hemorrhages. There was a recent thoracotomy incision on the left hemithorax. The right pleural space contained 600 cc. of amber fluid.

The heart weighed 420 gm. The chambers were moderately dilated, mainly on the right. The myocardium was flabby and presented a diffuse reddish discoloration, with paler areas in the subendocardial region. There were occasional petechiae on the endocardium. The coronary arteries showed occasional slightly elevated, small subintimal plaques.

The lungs weighed 1,360 gm. Crepitation was decreased, particularly in the lower lobe of the right lung. Cut section showed a congested, wet lung. A moderate amount of mucoid material was found in the bronchi.

No intravascular bubbles were demonstrated upon opening the great vessels under water.

The spleen weighed 160 gm. Cut section showed a soft, reddish parenchyma with prominent lymphoid follicles.

The liver weighed 1,520 gm. Cut surface was pale and had a slightly greasy appearance.

No abnormalities of the pancreas and gastrointestinal tract were observed.

The kidneys weighed 125 and 135 gm. Cut surface showed only congestion.

The brain weighed 1,500 gm. The convolutions were slightly flattened and the sulci slightly narrowed. The cerebral vessels were prominent and dilated, mainly around the ventricles in the subependymal areas.

Microscopic: Viscera.—The heart showed diffuse congestion of the myocardium. The myocardial fibers showed marked fragmentation.

Fig. 6. Pulmonary congestion, severe. Hematoxylin and eosin stain. ×30. AFIP Neg. No. 60-1731.

The lungs showed diffuse congestion (Fig. 6) and large patchy areas in which the alveoli were filled with amorphous eosinophilic material.

The spleen showed marked congestion of the red pulp and focal areas of hemorrhage.

The pancreas showed marked postmortem autolysis.

The liver showed moderate congestion of the central veins and sinusoids. There was a minimal fatty metamorphosis (Fig. 7).

The kidney showed advanced autolytic change. There was moderate congestion.

The thyroid, prostate, testes, and adrenals showed moderate congestion.

Brain.—The brain showed moderate congestion and edema (Fig. 8). Some of the neurons in the thalamus and cortex showed

*Prosector: Dr. A. Santamaria, University of Kansas.

signs of degeneration consisting of an increased eosinophilia of the cytoplasm, sharpening of the nuclear border, and increase of the pericellular space consistent with terminal hypoxemia. There were no areas of ischemic necrosis observed. No fat embolism was found in the lungs, kidney, or brain.

Case 3.—This forty-year-old Air Force pilot was flying with an instructor pilot in a T-33 jet trainer at an altitude of 32,000 feet with cabin pressurized at 20,000. Twenty-six minutes after take-off, he switched off the front windshield defroster and told the instructor pilot that the cabin pressure had dropped from 20,000 to 23,000 feet. Two minutes later, he complained of pain in his shoulder, spots in front of his eyes, and dizziness. When asked to check the "quick disconnect" of his oxygen hose, he cried, "That's it, that's it!" When told to fix it, he said, "I can't, I hurt too much." The patient began to breathe heavily and slumped to the left, then stopped breathing. The instructor pilot quickly landed the aircraft—a total of twenty-four minutes after the onset of symptoms. The patient was pronounced dead upon removal from the aircraft, three to five minutes later.

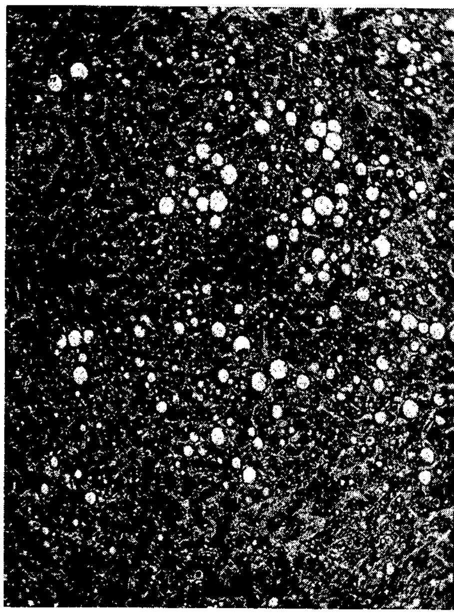

Fig. 7. Fatty metamorphosis of the liver. Hematoxylin and eosin stain. ×65. AFIP Neg. No. 60-1731.

Fig. 8. Cerebral congestion and edema. Hematoxylin and eosin stain. ×45. AFIP Neg. No. 60-1731.

*Postmortem Examination**

Gross.—The autopsy was begun twelve hours after death. The body was that of a well-developed, well-nourished, middle-aged white male. (Records show that he weighed approximately 170 pounds and measured approximately 70 inches.) There was marked cyanosis of the face and neck. The panniculus measured 3 cm. There was no hydrothorax or pneumothorax.

The heart weighed 400 gm. There were a few scattered subepicardial punctate hemorrhages in the left ventricle. The coronary arteries showed no sclerosis. There was no evidence of myocardial infarction.

The lungs weighed 1,250 gm. and were

*Prosector: Major R. E. Kellenberger MC, USA.

Fig. 9. Bullous emphysema. Hematoxylin and eosin stain. ×11. AFIP Neg. No. 60-1731.

Fig. 10. Bullous emphysema. Hematoxylin and eosin stain. ×25. AFIP Neg. No. 60-1731.

overexpanded and protruded from the pleural spaces. Crepitus was diminished in all lobes, and the lungs presented a "feather pillow" sensation with loss of elasticity. Both lobes showed numerous subpleural bullae (Fig. 9), the largest measuring 4 cm. in diameter and situated on the anterior inferior aspect of the left upper lobe. Cut surface showed edema and congestion.

The spleen weighed 500 gm. and showed marked acute congestion. One mediastinal lymph node measuring 2 x 1 x ½ cm. showed, on cut surface, multiple small granulomas.

The liver weighed 2,250 gm. and showed marked acute congestion.

The kidneys weighed 250 gm. each. Cut surface showed marked acute congestion.

The stomach showed marked congestion of the mucosal vessels, and there were several small foci of ectopic gastric mucosa in the esophagus.

The pancreas, thymus, adrenal, and pituitary appeared normal.

The brain weighed 1,750 gm. and showed marked edema with flattening of the gyri and narrowing of the sulci as well as tentorial notching on the swollen uncal gyri. There was no cerebellar pressure cone. Cut surface showed only edema.

Microscopic: Viscera.—The heart showed marked congestion and minimal subepicardial hemorrhage of recent origin. The lungs showed a patchy confluency of the alveolar spaces (Fig. 10). In some areas, loose ends or "spurs" characteristic of emphysema were seen (Fig. 11). There were focal areas of hyalinization and thickening of alveolar walls. Some of the bronchi showed a thick basement membrane and scattered eosinophils and mononuclear cells infiltrating the peribronchial tissue. In focal areas there was squamous metaplasia of the bronchial mucosa.

The liver showed a moderate fatty metamorphosis in a normal lobular pattern. The vacuoles were located primarily in the periportal area.

The adrenal glands showed marked congestion (Fig. 12), particularly in the zona reticularis.

Fig. 11. Pulmonary emphysema "spurs." Hematoxylin and eosin stain. ×60. AFIP Neg. No. 60-1731.

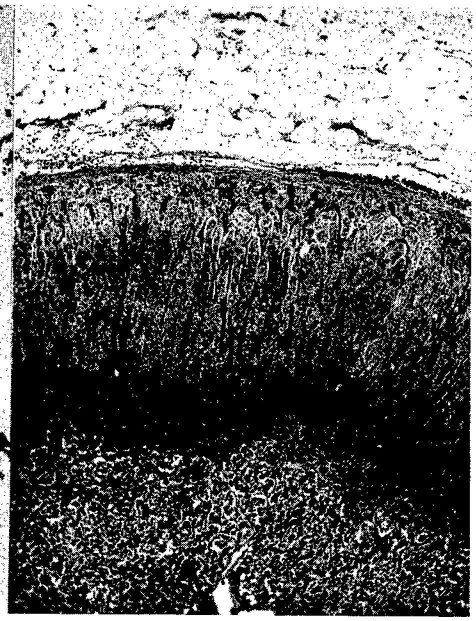

Fig. 12. Congestion of adrenal gland, severe. Hematoxylin and eosin stain. ×30. AFIP Neg. No. 60-1731.

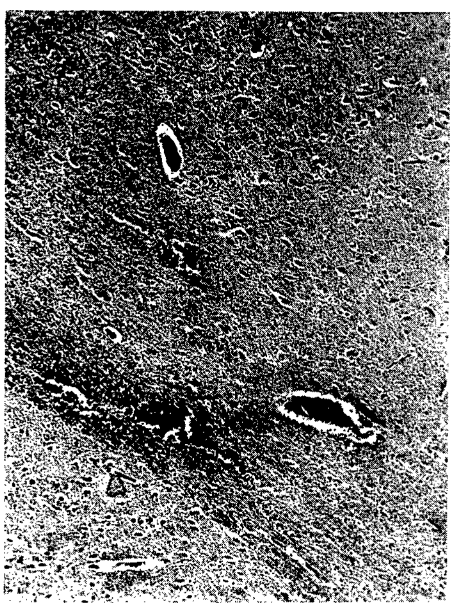

Fig. 13. Cerebral congestion and edema, severe; perivascular hemorrhage, minimal. Hematoxylin and eosin stain. ×55. AFIP Neg. No. 60-1731.

The spleen showed marked congestion and interstitial hemorrhage. The lymph node showed multiple fibrotic nodules. No etiologic agent was seen.

Brain.—Sections of the cerebrum showed marked congestion of the vessels, increased clear spaces around the cells, and minimal vacuolization of the ground substance characteristic of edema. There was diffuse shrinkage of the nerve cells of the cortex. This change was probably related to the massive brain edema. In the subcortical white substance, there were vessels with a finely fibrillary fibrosis of the adventitia and/or lipid-laden macrophages in the adventitial spaces. Adjacent to a small artery, in the ansa lenticularis, there were lipid-laden macrophages and cells containing granular hemosiderotic pigment. In the basal part of the external capsule, there was minimal perivascular hemorrhage (Fig. 13).

Special Stains.—ORO, Lillie, and PTAH stains failed to show fat emboli or ischemic areas of necrosis.

TABLE I. HISTORY IN THREE CASES OF DECOMPRESSION SICKNESS

	Case 1	Case 2	Case 3
1. Altitude			
Ambient	29,000 feet	33,000 feet	32,000 feet
Cabin	22,000 feet	33,000 feet	20,000 feet
2. Duration at altitude prior to symptoms	30 minutes	90 minutes	26 minutes
3. Survival	13 hours	9 hours	Approximately 20 minutes (sudden death)
4. Symptoms			
Neurologic	Unconsciousness	None	Scotomata; dizziness
Pain	Chest	Abdomen, legs, and left knee	Shoulder
Pulmonary	Cough	Dyspnea	None
Other	Terminal fever 103°	Nausea; weakness	None

TABLE II. PHYSICAL FINDINGS IN THREE CASES OF DECOMPRESSION SICKNESS

	Case 1	Case 2	Case 3
Age (years)	36	32	40
Height (inches)	73	65	70
Weight (pounds)	235	241	170
Cyanosis	Moderate	Moderate	Marked
Shock	Marked	Marked	Dead on landing
Neurologic	Absent deep tendon reflexes; flaccid extremities	Facial weakness; dysphagia, mild	Dead on landing
Other	Rales, minimal	Tender left calf; tender abdomen	Dead on landing

DISCUSSION

A summary of the salient points of the history, physical findings, and pathologic findings of the three cases is given in Tables I, II, and III, respectively. Case 1 presents a typical history and typical pathologic findings of decompression sickness. Case 2 presents a typical history but a relatively nonspecific pathologic picture. Case 3 presents an atypical history as well as nonspecific pathologic findings.

Case 1[13] is considered typical because of the remarkable similarity of the history and pathologic findings with two cases reported by Haymaker et al.[10] All were somewhat older, obese pilots who developed neurologic symptoms at

TABLE III. PATHOLOGIC FINDINGS IN THREE CASES OF DECOMPRESSION SICKNESS

	Case 1	Case 2	Case 3
Interval between death and autopsy	22 hours	15 hours	12 hours
1. Cerebral edema	Moderate	Moderate	Marked
2. Ischemic infarcts	Present	Absent	Absent
3. Foramen ovale	Patent	Unknown	Closed
4. Pulmonary congestion and edema	Marked	Moderate	Moderate
5. Fatty liver	Marked	Minimal	Moderate
6. Fat embolism	Minimal	None found	None found
7. Petechiae	None found	Gingiva; endocardium; conjunctiva	Subepicardial hemorrhage
8. Pleural effusion	200 cc. - 150 cc.	600 cc.	None
9. Other pathology	None	None	Vesicular and bullous emphysema

altitude and quickly lapsed into profound shock and died six to thirteen hours later. All had cerebral edema, patent foramen ovales, fatty livers, and ischemic infarcts in the brain.

Case 2 showed similarities to Case 1 and many of the previously reported cases.[1,9,10] The age, obesity, and clinical course were not unlike many of the characteristics of the reactors in flight or in chamber runs.[3] The cerebral edema, fatty liver, and signs of secondary shock (petechiae, effusions, visceral congestion and edema) are also findings in common. Conspicuous by their absence, in comparison with the previously mentioned cases, are ischemic infarcts in the brain and fat embolism in Case 2. The presence of a patent foramen ovale was not mentioned in a detailed autopsy protocol. The lack of these findings does not detract from the diagnosis of decompression sickness, since, in the tabulations by Fryer,[9] ischemic infarcts were found in only four of fourteen cases specifically examined for them, and fat emboli were found in only a few of the cases examined.

Case 3 is atypical as to somatic type and history, and there is a paucity of pathologic findings. For these reasons the cause of death can, at most, be only speculative; but on the basis of the circumstances, symptomatology, and elimination of other possible diagnoses, it is our opinion that this represents a case of fatal decompression sickness.

The prominent pathologic findings in this case were (1) marked cerebral edema, (2) pulmonary emphysema, (3) moderate fatty liver, and (4) petechiae, pulmonary congestion, and edema. The cause of the marked cerebral edema, which in itself could have caused the death, is unknown, but this finding undoubtedly has some relationship to this disease since it is common in most of the other fatalities. The cause of the emphysema is not known; the findings of chronic bronchitis and thickened basement membranes with eosinophilic infiltration suggest asthma, but this could not be substantiated by the past medical history. The role played by the fatty liver is not known; however, all the reported deaths have shown fatty metamorphosis to some degree. Rait[15] places great emphasis on this finding as a predisposing factor for the development of decompression sickness.

Because of the rapidity of death, which is an unusual factor in this case, hypoxia was considered. This was discounted, however, on the basis of (a) the absence of discrepancies in the oxygen system and (b) the history of severe pain, which is not a feature of death by hypoxia.[6]

Spontaneous pneumothorax was specifically looked for and found to be absent.

Carbon dioxide narcosis seemed unlikely, since death from this cause occurs more slowly and is usually preceded by symptoms of severe emphysema.[7]

Cardiovascular disease was given major consideration. The coronary arteries, however, were only mildly sclerotic and were widely patent, and there was no evidence of any present or past insults to the myocardium. Therefore, this cause was discounted.

Decompression sickness seems to be the most likely cause of this fatality. Certainly the altitude of 20,000 feet is compatible with the development of symptoms, and if there was an element of decompression, as suggested in the history, it was slight and would only tend to increase the likelihood of symptom development. Age may have been a factor, since older pilots are more apt to develop decompression sickness.[12] The symptoms of scintillating scotomata and dizziness are the most common neurologic manifestations of decompression sickness,[8] and the severe shoulder pain may have been the pain of "bends," which commonly affects that joint.[8]

The pre-existing disease, emphysema, may have been an important predisposing factor. Pulmonary emphysema can be associated with an increase in blood CO_2 content,[5] and increases in blood CO_2 have been shown to facilitate bubble formation in decompression.[4]

Lastly, the absence of specific pathologic findings in the brain does not preclude the diagnosis of fatal decompression disease, because ischemic infarcts were found in only a few of the published cases and because the absence may be a relative one in that there was insufficient time for changes to develop.

The mechanism of death in Case 1 would seem to be in accordance with that proposed by Haymaker et al[10] of aero-emboli traversing a paradoxical route through the foramen ovale to the brain and producing ischemic infarcts and subsequent shock. On the other hand, the absence of the ischemic infarcts in Case 2 and the probable closed foramen would tend to dispel the aero-embolism theory and favor some of the hypotheses such as generalized tissue damage proposed by others.[8,11] Pfrommer has recently commented, "Today we may say that the symptoms of decompression sickness result from the evolution of gaseous nitrogen, and possibly of other body gases, during environmental atmospheric pressure changes. The symptoms are the effects of the gases' influence, in some incompletely understood manner, on adjacent or distant vascular and somatic tissue. It is speculative to say more than this."[14] This statement summarizes the present state of knowledge on the causation and our present contention in this paper that much has been written but little is actually known about the basic pathogenesis of this disease.

SUMMARY

Three fatal cases of decompression sickness have been presented. Case 1 presents a typical history and specific pathologic findings. Case 2 presents a typical history of the syndrome, but there is a paucity of pathologic findings to explain the death. Case 3 is somewhat atypical in history and also presents a paucity of pathologic findings. Reasons were given for the diagnosis of death as a result of decompression sickness.

From a review of the fatalities in the literature and a comparison with these cases, it is obvious that there is still much to be learned about the disease and the pattern of pathologic findings in the fatal cases.

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Man In Space

• NASA is hammering out its program upstream of Mercury at this writing. A few trends are now apparent. Most important is a decision to abandon the Atlas-Centaur as a booster for a manned space vehicle. NASA's next manned vehicle after Mercury will be a multi-man space observatory launched by Saturn. NASA will not pursue Centaur because it is a "dead-end street," according to one of its officials.

• Centaur will be utilized, however, in the advanced man-in-space program to develop re-entry vehicles with a lift shape. It will be capable of testing the basic "module" of the Saturn system—the escape, re-entry, and recovery vehicle for the crew. This vehicle will also have control and communications capability.

• It is possible Saturn will also be pressed into service for upstream man-in-space vehicle experiments even before it is ready for operational use. Since the last four Saturns of the 10-vehicle test program will have all-live stages, they will have a payload capability far in excess of that needed for their own test instrumentation. As a consequence, NASA is studying the possibility of using them to stage re-entry trajectories at escape velocities —such as would be required for a manned circumlunar vehicle returning to earth.—From *Astronautics*, August, 1960.

Significance of Elevated Lactic Acid in the Postmortem Brain

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THE PHYSIOLOGIC adversities encountered by man at high altitudes are well known. Incapacitation by hypoxia, for example, has been established as a contributory factor in aircraft accidents.[7] The increased emphasis on the medical investigation of aircraft accidents has focused attention on the need for a method of postmortem detection of acute antemortem hypoxia.[9] Lack of suitable histopathologic criteria prompted studies at the Royal Canadian Air Force Institute of Aviation Medicine and the School of Aviation Medicine, USAF Aerospace Medical Center (ATC), to explore the possibility of a biochemical indicator of antemortem hypoxia in postmortem tissue. Preliminary studies suggested that the lactic acid content of the brain might provide such a criterion.

Franks and coworkers[5,8] exposed mice to 100 per cent nitrogen which caused death within ten to fourteen minutes. The brains of these mice, analyzed up to sixteen hours postmortem, always contained significantly higher concentrations of lactic acid than brains from control mice decapitated and examined after the same periods. These studies were extended by Van Fossan and Clark,[11] who found a graded response in the postmortem increase of brain lactic acid, depending upon the simulated altitude and the duration of exposure. Increased levels of lactic acid in brains of exposed animals were demonstrable six, twenty, and thirty hours after death in the rat, dog, and rabbit, respectively. These experimental findings were promising; therefore a program was initiated at the Armed Forces Institute of Pathology (AFIP) to explore the value of using the level of brain lactic acid as an indicator of antemortem hypoxia in aircraft accident fatalities.

Aircraft Accident Studies.—Frozen, non-fixed tissue from victims of aircraft accidents is submitted to the Armed Forces Institute of Pathology by the U. S. Air Force, Navy, and Army. Since October, 1956, the brain lactic acid level has been routinely determined in these cases. Within the experimental confines of the test lactic acid levels over 200 mg. per cent in brain tissue were considered to be indicative of hypoxia, although the ele-

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From the Armed Forces Institute of Pathology.

Biological Sciences Division, Air Force Office of Scientific Research, Washington, D. C.

Presented at the Aerospace Medical Association meeting in Miami, Florida, May 9, 1960.

vated value did not distinguish between the causes of the hypoxia. In 775 aircraft accident cases in which this test was performed at the AFIP from October, 1956 to January 1, 1960, there were fifty-eight instances in which a value over 200 mg. per cent was obtained. In six instances there was definite evidence that the elevation was due to altitude hypoxia, in twenty-nine there was history of short survival in a shock state following the accident, in eight suffocation was the cause, in nine instances drowning was responsible, in two no history was available, in three cases a cause was doubtful, and in one the possibility was either hyperventilation or hypoxia.

Correlation of the elevated cases (above 200 mg. per cent) with the known circumstances of the accident reveals that a large number of these fatalities were not associated with altitude hypoxia but with such causes of death as drowning, suffocation and shock. These cases were all associated with conditions which produce a hyperglycemic response. Since glucose is a precursor of lactic acid, any condition inducing a hyperglycemia and the consequent rise in brain glucose might result in a postmortem increase of brain lactic acid.

Hypoxia produced by simulated altitude exposure or breathing low oxygen mixtures has been known to induce hyperglycemia, as cited by Van Liere,[12] Biddulph and Van Fossan.[1] Asphyxia following obstruction of the upper respiratory passage, for example, in strangulation or hanging, has resulted in blood sugar concentrations which exceed normal limits.[6] Furthermore, in cases of severe hemorrhage or shock, hyperglycemia appears to be a common occurrence.[3,13] Thus hyperglycemia appears to be closely allied with all conditions reported as associated with elevated lactic acid in the aircraft accident cases; altitude hypoxia is but one of many possible hyperglycemic stimuli.

Since hypoxia is a potent stimulus for elevating blood glucose and since glucose is the precursor for lactic acid, animal studies were carried out at the AFIP to explore the relationship between blood glucose and the postmortem lactic acid response.[4] Rats utilized in these studies were exposed to a simulated altitude of 32,000 feet for ten minutes; they demonstrated a marked rise in the concentration of blood glucose and in the postmortem level of brain lactic acid. Hyperglycemia without hypoxia was induced by glucose infusion, epinephrine, or electric shock, each of which caused an increase in the postmortem brain lactic acid comparable to levels in hypoxia. Conversely, when rats were given insulin to reduce the blood glucose concentration prior to being exposed to a simulated altitude, the elevated lactic acid response normally seen following hypoxia did not take place. In addition, the administration of various synthetic oral hypoglycemic agents prior to hypoxia significantly reduced the blood glucose level and postmortem brain lactic acid. Iodoacetate, which blocks the conversion of glucose to lactic acid, markedly inhibited the increase in brain lactic acid after hypoxia. In another experiment, rats were made hypoxic by simulated altitude exposure but then sacrificed at varying times after return to ground level. When the blood glucose level returned to normal the postmortem brain lactic acid showed a parallel drop.

These findings, when correlated with the findings on lactic acid in the human aircraft accident studies, suggest strongly that the elevated postmortem level of lactic acid attained in the brain is a reflection of the blood glucose. With the increased concentration of blood glucose, there is a concomitant increase in the lactic acid precursor (glucose) in brain tissue. After death, this substrate is anaerobically metabolized by surviving glycolytic mechanisms to lactic acid in the brain. An increased lactic acid found in the brain after a hypoxic episode probably results from the hyperglycemia induced, rather than from any unique contribution of the hypoxia itself.

SUMMARY

One must interpret cautiously the postmortem chemical changes observed in aircraft fatalities. Hypoxia is only one of many possible factors that might cause changes in the levels of blood glucose. The blood sugar response of individuals exposed to a given stress or nutritional regimen is known to vary widely. Both physical and psychological stresses encountered during flight may cause hyperglycemia as profound as that caused by hypoxia itself. The time required for descent prior to crash would cause variable changes in the blood and brain chemistry. The time and nature of the last meal are known to modify blood sugar concentrations. The lactic acid content of one part of the brain differs from that of another, so care must be exercised in sampling.[2,10] All these and perhaps other factors affect the lactic acid levels in the brain. Thus, the diagnosis of hypoxia during flight should not be based upon an arbitrary level of lactic acid *per se* in postmortem tissue as the sole criterion, but should be correlated with the history and circumstances of the accident.

High lactic acid values in the brain do not prove that there was hypoxic exposure, nor do low levels preclude this possibility. Nevertheless, the determination can be of value when used in conjunction with other evidence as an aid in reconstructing the events leading up to an aircraft accident.

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The Outer Radiation Belt

Analysis of the data obtained with the help of Sputnik III and the Soviet space rockets warranted the conclusion that the intensity of the outer radiation belt, girdling the Earth at an altitude of up to 37,260 miles, could vary scores of times, Professor Sergei Vernov declared in a recent report delivered at a general meeting of the Physics and Mathematics Department of the U.S.S.R. Academy of Sciences.

Soviet scientists, he said, linked this phenomenon with the magnetic storms which interfered with the circulation of charged particles in the radiation belt.

Describing the structure of the outer radiation belt, Professor Vernov said that it had now been proved that it consists of two main components —electrons of relatively low energy of up to 10,000 to 100,000 electron volts and high energy electrons of up to 1 to 3 million electron volts.

So far there was no theoretical explanation for the existence of such high energy electrons.

However, one thing was clear, namely, that they must generate gamma radiations so powerful that they would present a serious danger to future space travelers.

Professor Vernov drew attention to the possibility of the Earth's magnetic field at high altitudes being affected by intensive fluxes of low energy electrons.

According to data obtained from Sputnik III, the distance from the surface of the Earth to the outer radiation belt at one and the same latitude differed sharply at various points. In the U.S.S.R., for instance, it was 993 miles, and in the United States it was as low at 372 miles.

Professor Vernov believes that this is due to the displacement of the magnetic pole in relation to the centre of the Earth.

The artificial satellite technique, he said, made it possible to determine this displacement more accurately and it amounted to approximately 310 miles and not 186 miles, as was hitherto believed.—From *Spaceflight*, April, 1960.

Ability of Pilots to Perform a Control Task in Various Sustained Acceleration Fields

CAPTAIN HARALD A. SMEDAL, MC, USN, BRENT Y. CREER, and RODNEY C. WINGROVE

MANNED satellite or lunar vehicles which employ lift in order to minimize the effects of aerodynamic heating and those of deceleration upon re-entry may require a certain degree of pilot control. The acceleration stresses imposed upon the pilot will vary with the lift and drag of the vehicle. The pilot's ability to tolerate these stresses and at the same time to adequately control the vehicle depends on his position in the vehicle relative to its direction of motion.

Numerous investigations[1,2,4,5,6,10] have indicated that man can withstand the magnitude of deceleration required of the vehicle during re-entry if he can be positioned so that the acceleration force is applied in a direction transverse to the spinal axis of the body. Preference so far has been given largely to the placement of the pilot in a position in which these forces are at right angles to the spinal axis, applied from the ventral to the dorsal surface of the body. This direction of acceleration has been variously described as frontward, positive n_X, and, more colloquially in the vernacular of the aviator, "eyeballs in" acceleration. The pilot position is a backward facing one in relation to the direction of motion of the vehicle.

Of considerable interest, especially in the high lift-drag-ratio vehicle which has the potentiality of being maneuvered to a selected landing site, is the use of the forward-facing seated position. In this position the accelerations would again be applied largely transverse to the spinal axis of the body but in a dorsal to ventral direction. The direction has been described as backward, negative n_X, or "eyeballs out" acceleration. Because of the lift of the vehicle a great deal of acceleration is probably in the direction which may be described as headward, n_N, or "eyeballs down" acceleration. Varying amounts of a combined headward and backward, negative n_X and n_N or "eyeballs down and out" acceleration will also be encountered as the flight path of the vehicle is altered. Figure 1 illustrates the acceleration nomenclature which will be used for the most part hereafter.

Some of the lack of interest in the forward-facing position of the pilot, we believe, has stemmed from the fact that no adequate anterior support or restraint has as yet been developed. It is stated[2] that positive n_X acceleration is best tolerated when compared with negative n_X acceleration. The difference was said to be so great as to justify rotating the pilot 180

From the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California.

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degrees if necessary in order that he face aft during re-entry. However, it was admitted that with an adequate anterior restraint there would probably be little difference, if any, in the tolerance levels.

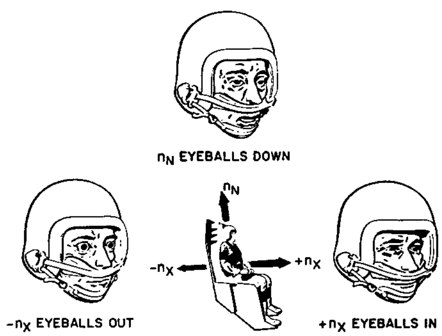

Fig. 1. Acceleration vectors and pilot vernacular for impressed acceleration.

In the past, it has been customary to measure acceleration tolerance largely on the basis of how many G's the individual could withstand without much regard for the many factors which influence these tolerances. For proper evaluation of human tolerance to acceleration one must exercise care to relate this tolerance to all appropriate variables. In crash survival one is interested in factors far different from those involved in the control of aircraft. Since it relates to satellite vehicle re-entry, we will endeavor to gauge tolerance by including five different factors which we feel are of greatest importance: the magnitude of the accelerative force, the rate of onset, the direction in which the acceleration is applied to the body, the duration of the acceleration, and last but most important, the performance capability of the pilot.

In order to explore some of the problems concerning entry vehicle controllability, a joint study was undertaken by the National Aeronautics and Space Administration, Ames Research Center and the Naval Air Development Center, Aviation Medical Acceleration Laboratory. The investigation was not intended to be a comprehensive study in the field of controllability of re-entry vehicles. Its purpose was to probe into some of the problems by investigating the ability of the pilot to perform a meaningful task while immersed in moderately high varied fields of acceleration for prolonged periods of time and seated in a forward-facing position.

METHODS

The major piece of equipment used in this program was the NADC, AMAL centrifuge employed as a flight simulator and operated as a closed loop system.[3]

Six subjects were used in this study. They were recruited from the various NASA Research Centers, the Naval Aviation Test Center, Patuxent River, Maryland, Edwards Air Force Base, California, and NADC, Johnsville, Pennsylvania. Some had had previous centrifuge experience. All could be considered sophisticated and highly motivated subjects.

The subjects were required to carry out a relatively complex tracking problem.[7] The control task used was representative of that which might be encountered in a re-entry of the earth's atmosphere. Certain "flight" information was presented to the subject on an instrument panel.

The pilot efficiency was calculated as the accumulated tracking error compared with the accumulated excursions of the target and is expressed in the following equation:

$$\text{P.E.} = \frac{\sum \theta_i^2 - \sum e^2}{\sum \theta_i^2}$$

where

$\sum \theta_i^2$ = sum of the target excursions

$\sum e^2$ = sum of the tracking error excursions

The entire investigation was divided into three phases. The first phase was devoted to the evaluation of side controllers. The second phase obtained information on the combined effects of magnitude and direction of applied acceleration force and complexity of control task on pilot performance. The third phase was designed primarily to obtain data regarding tolerance to acceleration. Some of the third phase experiments were interspersed in the first and second phases in order to avoid fatigue.

The controller chosen from phase one and used for the majority of the phase three runs was a two axis finger-held side controller.[8] Pitch and roll control inputs were made with this controller. Yaw control was made with a set of toe pedals.[9] The toe pedal yaw control differs from the conventional rudder pedals in that control is performed by flexion and extension of the foot about the transverse axis of the ankle joint in contrast to the rudder pedals which are manipulated by flexion and extension of the lower leg at the knee.

Fig. 2. Over-all view of restraint system.

One of the most critical elements in carrying out this program and upon which the results that would be obtained depended so greatly was the development of the restraint system[9] shown in Figure 2.

Additional protective devices against the accelerations used in this study consisted of the g-suit and elastic bandages for wrapping the legs and arms.

Recordings were made of the electrocardiograph, respiration, pilot efficiency and acceleration pattern on a four channel Sanborn recorder. The electrocardiogram electrodes were positioned on the lateral aspect of the chest. Respiration was measured by means of a chest strap containing a strain gauge. The rate of onset for all acceleration was approximately 0.1 G per second. The duration of all experiments was measured as the total time spent at 90 per cent of the maximum acceleration. Each tolerance run was preceded by a static 1 G run intended to serve as a base line.

TABLE I. ACCELERATION-TOLERANCE PERFORMANCE DATA

	Subject	Magnitude In g's	Tolerance Time	Tracking Efficiency Per Cent	Efficiency Decrement Per Cent
Eyeballs out	RC	7	4′47″	45	34
	JH	7	2′23″	25	15
	JH	7	3′48″	55	5
	RI	7	2′45″	50	20
Eyeballs down and out		5.7	5′48″	—10	67
	RS	7.1	1′15″	0	39
		8.5	20″	25	30
		5.7	3′35″	35	—10
	JW	7.1	2′42″	45	5
	MT	5.7	3′07″	50	25
Eyeballs down	RI	6	6′27″	50	20
	MT	6	5′13″	53	29

RESULTS

The results of the phase three (3) or tolerance runs are tabulated in Table I. From these data and that of the tolerance to acceleration studies reported by others, it was possible to construct time-tolerance-to-acceleration boundaries. In addition it was possible to relate these boundaries to the accelerations anticipated during re-entry from circular or parabolic velocities. Figure 3 shows these boundaries and requirements. The left dashed curve illustrates maximum G's and the length of time during which they would have to be endured by an occupant of a ballistic vehicle entering the earth's atmosphere from a circular orbit. Note that this is not a time history but rather each point on the curve represents at atmosphere re-entry trajectory with a constant initial entry angle. The curve shows, for example, that by proper drag modulation the maximum G's which the vehicle would encounter during entry could be 10 G. This level would have to be endured for about 0.7 minutes. The right dashed curve illustrates the ballistic vehicle entry from parabolic or lunar velocity. It should be noted that the "eye balls out" and "eye balls in" boundaries are seen to be superimposed. It was demonstrated in this study that with suitable restraint, the tolerance to "eye balls out" acceleration was at least as good as the tolerance to "eye balls in" accelerations. If man is properly restrained he can withstand the acceleration stresses required of re-entering from circular velocity. However, in an entry from parabolic or lunar velocity, man's tolerance to acceleration could be exceeded.

The subjective and objective findings in this study involved primarily three body systems, visual, cardiovascular and respiratory. The latter is the most important.

The visual symptoms were of two distinct varieties. During the "eye balls out" accelerations, transient changes in visual acuity occurred. The acuity impairment could have been due to distortion of the corneal surfaces. Other possible but less probable causes are lens displacement or tilting of the retinal receptors. Loss of acuity was never a critical factor. The other visual symptoms involved alterations in visual fields and "graying" or "blacking out." These usual symptoms were seen only during those runs in which "eye balls down" accelerations were involved.

The cardiovascular difficulties involved primarily petechial hemorrhages, tissue fluid accumulation and transient arrhythmias. The petechial hemorrhages were seen in the lower extremities on all runs in which the "eye balls down" acceleration was a factor. Tissue fluid accumulation was seen in this same type of experiment. It was also observed in the forearms during "eye balls out" accelerations. Elastic bandages minimized but did not prevent these difficulties. Isolated premature beats were frequently seen in the "eye balls down" and "eye balls in" runs but never in the "eye balls out" runs. In one case during a 6 G "eye balls down" run, a series of four premature beats appeared each one coupled with a normal beat producing in effect a transient bigeminal or coupled rhythm, ventricular in origin and apparently from a single focus. There were S-T segment changes and elevations in the amplitude of T waves.

The respiratory findings were of the greatest interest. The method used in

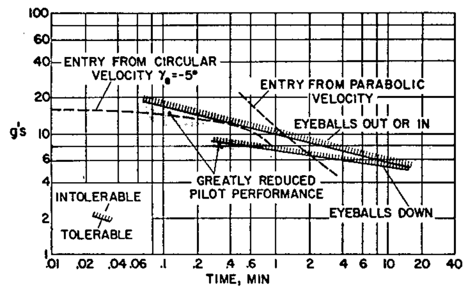

Fig. 3. Time tolerance to acceleration boundaries.

recording respiration did not accurately record more than respiratory rate, although it was possible to obtain certain objective impressions from a study of the respiratory patterns. All subjects agreed that respiration was the least difficult during "eye balls out" acceleration and most difficult during "eye balls in" acceleration, and a study of the respiratory tracing supports these subjective findings. During the "eye balls in" accelerations a lowering of the mid capacity level into the reserve air volume was frequently noted. The relative ease of respiration during the "eye balls out" as compared with the "eye balls in" acceleration can be largely explained on the basis of the mechanics of respiration. During the "eye balls out" acceleration, the inertial forces of acceleration assist in increasing the anterior-posterior diameter of the chest which normally occurs during inspiration. During "eye balls in" acceleration, these same forces tend to prevent this by chest compression. Exhalation by the same token is enhanced by "eye balls in" acceleration but impaired by "eye balls out" acceleration. However reduction in exhalation during "eye balls out" acceleration served to leave the chest ex-

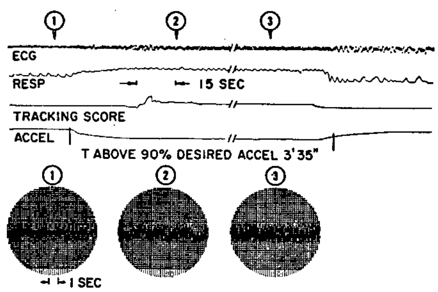

Fig. 4. Sanborn recorder data; subject J. W.; acceleration $n_X = -4$. $n_N = +4$.

panded with a larger reserve air volume. Figure 4 illustrates an effective respiratory pattern established by one of the subjects during a diagonal vector run. Note how he appears to have filled his lungs more completely with air as the acceleration came on and proceeded to breath off the top of a larger lung volume. This same procedure is often seen during muscular exercise in which the residual air is increased and the vital capacity is decreased. Alteration in respiratory mechanics observed in this type of run resulted in a more efficient oxygenation of blood through more thorough ventilation of the alveoli. There is a greater volume of reserve air remaining in the lung at the end of expiration.

SUMMARY

It has been demonstrated that a well trained subject such as a test pilot can successfully perform a moderately complex tracking task, representative of a re-entry control problem, while being subjected to relatively high and varied accelerations for prolonged periods of time. Maximum meaningful levels of acceleration obtained were approximately six times gravity for six minutes and varied somewhat with the direction of acceleration. Critical factors in the establishment of these levels were the restraint system and the quality of the subjects.

The subjective and objective physiological observations involved the visual, cardiovascular and respiratory systems.

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Hemodynamic Changes during Forward Acceleration

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MODERN technology in rocket research has placed men at the threshold of space flight, but present booster vehicles require accelerations of relatively great magnitude in order to attain the required orbital velocity. Knowledge of the physiological effects of these alien accelerations on the cardiovascular system are limited and ill defined. Investigation of the effects of headward accelerations of this order of magnitude in which the vector is parallel with the long axis of the body showed that in spite of augmented compensatory changes, the accentuated inertial effects upon the cardiovascular system in the upright position, resulted in the ultimate impairment of venous return, and reduction of cardiac output. Thus blackout and unconsciousness have limited tolerance to acceleration in this vector, and even the use of G-suits has only slightly improved this tolerance.

Forward acceleration in which the acceleration vector is perpendicular to the long body axis has provided a means of increasing man's tolerance. In this position, he has endured the inertial effects of more than 16 G without protective devices, and has not been limited by blackout or unconsciousness. Major effects produced by forward acceleration include severe chest pain, dyspnea, and progressive respiratory embarrassment with reduction of vital capacity, tidal volume,[1] and an increase in Respiratory Equivalent[16] in spite of augmented respiratory frequency and minute volume.

Recent investigation[8] has shown marked impairment of cardiac dynamics during headward acceleration of relatively low magnitudes (3-4G), and less of an effect during forward acceleration. The purpose of this paper is to better define the cardiovascular parameters encountered during forward accelerations of high magnitudes for extended time periods.

METHODS

Eight mongrel dogs weighing between 10 and 12 kilograms, fasted for twelve hours except for water *ad libitum,* were lightly anesthetized with an intravenous injection of a 1 per cent solution of alpha chloralose (80 mgm./kgm.) in saline. In each animal an endotracheal tube was passed. Polyethylene catheters were placed in each femoral artery and one catheter was advanced into the superior vena cava via the jugular vein. All animals were given an intravenous injection of 30 mgm. heparin.

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Each animal was accelerated on the centrifuge in a special restraint system oriented perpendicular to the acceleration vector. The experimental protocol consisted of randomized 6, 10 and 14G acceleration plateaus of either five or ten minutes duration. Not every animal experienced the entire profile. Three control and three to five experimental observations were made during the course of each G profile, and one hour was allowed for recovery between experimental procedures.

Cardiac output was measured using the indicator-dilution technique as described by Stewart and Hamilton.[6,15]

The particular technique employed in this experiment is a modification of the original Stewart method for determining output by measuring changes produced in resistance of the arterial blood by the intravenous injection of a 4 per cent sodium chloride solution. Changes in indicator concentration during passage through the pulmonary circulation, and possible physiological effects of a hypertonic solution on flow dynamics were the obvious disadvantages of the technique as it was first used. Sapirstein[5] noted that the resistance of arterial blood was related to changes in erythrocyte concentration (hematocrit), and by directly recording hematocrit dilution of arterial blood induced by intravenous injection of autogenous plasma was able to determine the cardiac output. In order to eliminate the initial hemorrhage required to prepare the autogenous plasma, a solution of 6 per cent Dextran in isotonic saline was substituted. This synthetic preparation approximated dog plasma within 1 to 4 ohms as measured through a conductivity cell cuvette, within 5 to 10 milliosmols crystaloid osmotic pressure by direct measurement using a Fiske osmometer, and within 5 mm. Hg oncotic pressure by calculation.[9] The close approximation of this solution to autogenous plasma minimizes both indicator concentration changes during pulmonary transit and possible physiological alterations arising from the use of 4 per cent saline.

A rapid (10 ml./sec.) multiple injection syringe which automatically marked its injection midpoint was connected to the jugular venous catheter and was used to inject the synthetic solution to determine cardiac output. Hematocrit dilution curves were monitored through a conductivity cell cuvette attached to one femoral catheter in series with a constant speed (14 ml./min.) electromechanical withdrawal syringe. A second rapid withdrawal (100 ml./min.) syringe arranged in parallel through a stopcock manifold, allowed for withdrawal of an anerobic 20 ml. sample of arterial blood during acceleration. Arterial pressure was measured from the other femoral artery with a Statham strain gauge (0-75 cm. Hg) placed at the midchest position. Lead II of the ECG was monitored using subcutaneous electrodes. Respiratory frequency was recorded from a pneumograph and Statham gauge, and acceleration levels were monitored through a Statham accelerometer. All data were recorded on a photo-oscillographic recorder (Fig. 1).

The data reported consists of cardiac output, heart rate, stroke output, circulation time, mean arterial blood pressure, and respiratory frequency.

RESULTS

In Figures 2 and 3 control and experimental results are presented for 6, 10 and 14G levels. Standard deviations appear above each bar graph. Since progressive changes with respect to time at G were not observed in any of the parameters measured, mean data for each profile are grouped.

Physiological variables measured are summarized in Table I.

Comparison of control and G cardiac output values showed only small changes. There was a 14 per cent decrease at 6G, and 23 per cent decreases at 10 and 14G. Two sided "t" test evaluation with 95 per cent confidence limits, used for all analyses, showed significant changes only at 10 and 14G. However, the results even at 14G were within normal limits. Variability observed in cardiac output from one determination to another during control and experimental periods was similar to that observed by other investigators in which there was no mechanical control of respiration.[10,17] Mean control values for cardiac output (140-220

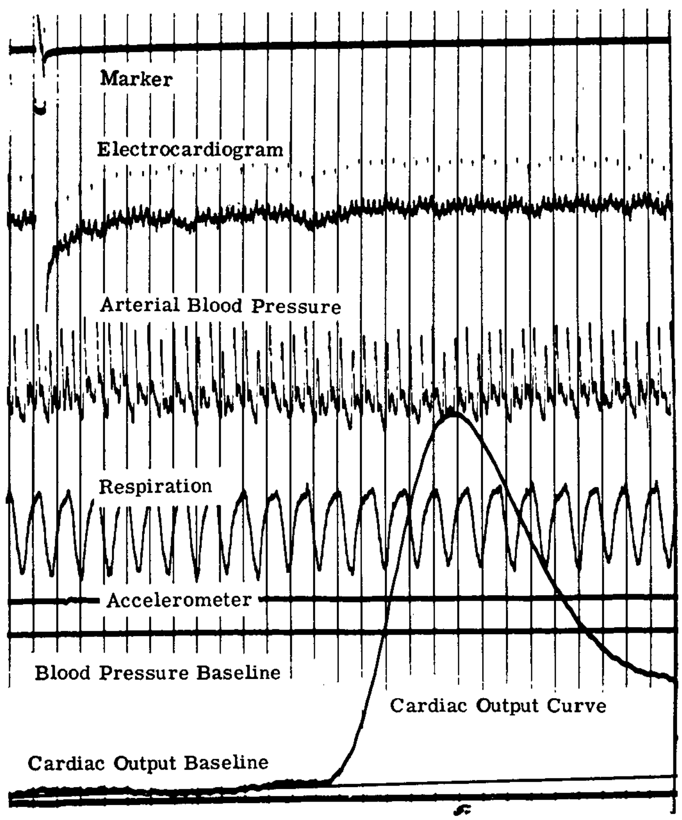

Fig. 1. Illustration of physiological variables recorded during forward acceleration in the dog.

ml./kgm./min.) agreed closely with those reported by others.[14]

Heart rate fell progressively with increments of acceleration. There was a non-significant 14 per cent decrease at 6G and a significant 28 per cent decrease at both 10 and 14G which correlated well with decreases noted in cardiac output. Consequently, stroke output, calculated by dividing minute volume by heart rate, was unchanged.

The superior vena cava to femoral artery conductivity cell circulation-time showed statistically significant increases at each G level; 18 per cent at 6G, 45 per cent at 10G and 50 per cent at 14G. This expected prolongation agreed physiologically in direction and approximate magnitude with the observed decrease in heart rate and unchanged stroke output during forward acceleration in these animals.

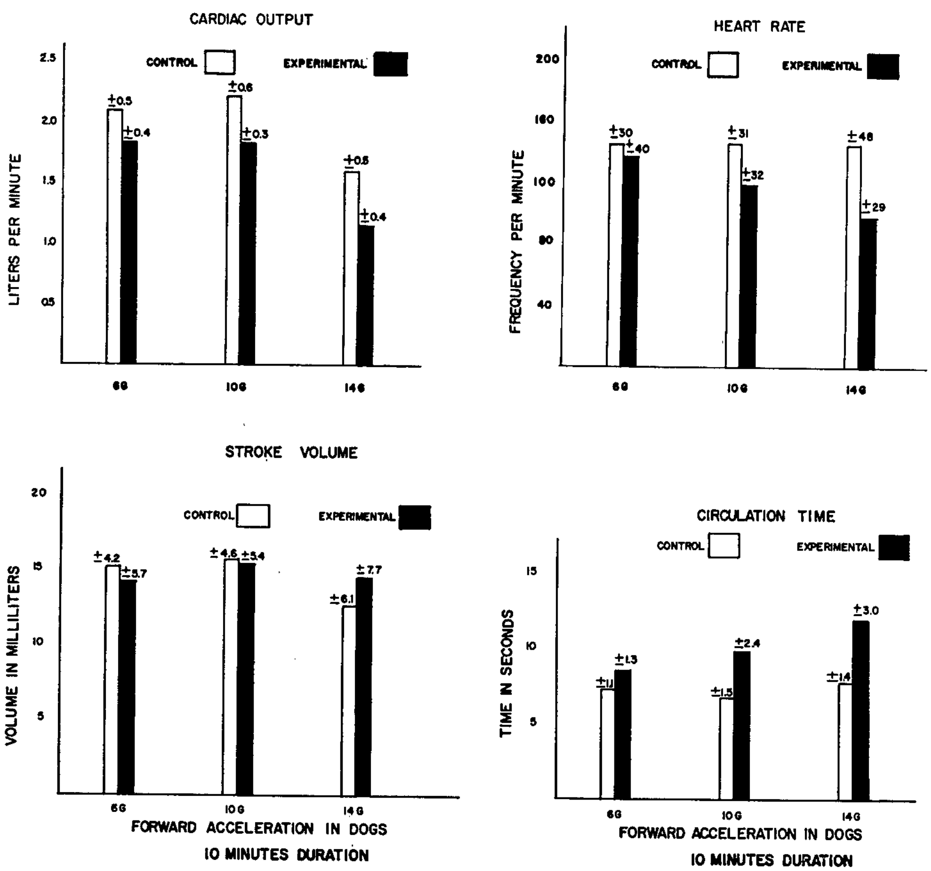

Fig. 2. Comparative changes in Cardiac output, heart rate, stroke volume and circulation time in the dog during forward acceleration. Mean values for seven dogs.

Mean arterial blood pressure measured at the midchest position showed no change at 6G, and significant 14 per cent and 20 per cent decreases at

10 and 14G respectively. Total peripheral resistance calculated from the blood pressure and cardiac output

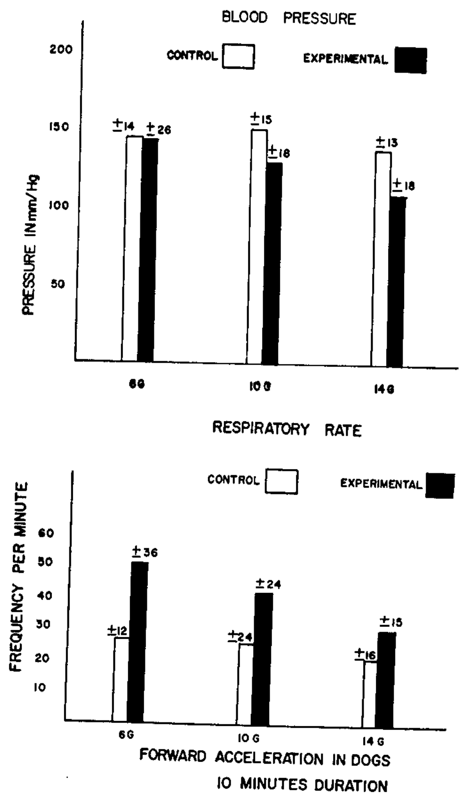

Fig. 3. Changes in blood pressure and respiratory rate in the dog during forward acceleration. Mean values for seven dogs.

showed no changes at any G. The reasons for not presenting these data will be discussed.

Respiratory frequency was increased at all G levels; 90 per cent at 6G, 70 per cent at 10G, and only 35 per cent at 14G. In man there is a progressive increase in respiratory frequency with increments of acceleration. Whether or not this downward trend was inherent in these experimental circumstances or is a species variation is not known.

TABLE I. SUMMARY VALUES OF PHYSIOLOGICAL OBSERVATIONS MADE DURING A STUDY OF HEMODYNAMIC CHANGES DURING FORWARD ACCELERATION IN SEVEN DOGS.

	Cardiac Output (liters/min)	
Cont 2.16±.5 6G 1.86±.4	Cont 2.25±.6 10G 1.73±.3*	Cont 1.62±.5 14G 1.28±.4*
	Heart Rate (beats/min)	
Cont 146±30 6G 138±40	Cont 146±31 10G 119±32*	Cont 145±48 14G 98±29*
	Stroke Output (ml/stroke)	
Cont 15±4 6G 14±6	Cont 16±5 10G 15±5	Cont 13±6 14G 14±8
	Circulation Time (seconds)	
Cont 7±1.1 6G 8±1.3*	Cont 7±1.5 10G 10±2.4*	Cont 8±1.4 14G 12±3.0*
	Mean Arterial Blood Pressure (mm Hg)	
Cont 145±14 6G 144±26	Cont 152±15 10G 131±18*	Cont 139±13 14G 110±18*
	Respiratory Frequency (breaths/min)	
Cont 27±12 6G 52±36*	Cont 26±24 10G 44±24*	Cont 22±16 14G 30±15

*$P < .05$

At the end of each run every animal showed marked cyanosis of the abdomen, buccal mucosa, and tongue. Arterial blood samples anerobically drawn prior to terminating each G profile were visually compared with pre-run samples, and in every case qualitative evidence of arterial desaturation was observed. These changes appeared somewhat less marked at 6 G. Further investigations are in progress to verify and quantitate these clinical observations.

Positive autopsy findings were confined to the lungs and frontal sinuses and will form the basis of a communication concerning pathological changes.

DISCUSSION

Although forward acceleration has been substituted to minimize the cardiovascular impairment of headward acceleration the physiological effects have not previously been adequately measured. There is little alteration in cardiac output at the G levels studied, and changes that are observed closely correspond to decreases in heart rate and not to a fall in the stroke output of the heart. The jugular vein—femoral artery circulation time is concomitantly prolonged. These data show a striking maintenance of cardiodynamic function during forward acceleration up to 14G.

Gauer[4] using x-ray cinematography in animals demonstrated a progressive decrease in the size of the great veins, and in cardiac dimensions during headward acceleration. This shows a marked impairment in the venous return, and effective blood volume which ultimately determine the left ventricular output. Hershgold and Steiner[8] in dogs and Lindberg, Headley, and Wood[12] in man have corroborated these observations by demonstrating a progressive failure of the cardiac output with an augmentation of compensatory tachycardia resulting in a decrease in left ventricular stroke output during headward acceleration. These observations are in marked contrast to those observed during forward acceleration.

In this group of experiments, arterial pressure measured at the midchest position fell commensurate with changes observed in cardiac output resulting in an unchanged calculated total peripheral resistance (TPR). However, this observation needs careful and cautious interpretation, and cannot be considered to reflect resistance changes throughout the vascular system. The mass of the blood filled vascular system at an acceleration of 14G has a weight-equivalent greater than mercury. Since the heart moves posteriorly during forward acceleration,[7] small differences in position of the blood pressure strain gauge in relation to the actual heart level results in large blood pressure changes which do not reflect true differences in blood pressure. Therefore, the determination of blood pressure or total peripheral resistance in terms of the neuro-humoral regulation of the circulatory system during acceleration, in relation to surface anatomy, is physiologically meaningless. Intravascular or differential manometers, properly G-oriented should alleviate this problem.

An interesting decrease in heart rate was observed and probably reflects a differential stimulation of the carotid sinus baroreceptors compared with those in and around the heart and great vessels which lie more arteriorly.

Respiratory frequency increases progressively with increasing forward acceleration in man, but we cannot explain why there was not a progressive increase in these dogs.

On termination of an experimental 10 or 14 G run, all animals showed marked cyanosis of the abdomen, mouth and tongue. This was somewhat less noticeable at 6 G. Arterial blood samples, when compared visually to control samples, were remarkably desaturated. However, a discussion of ventilation and perfusion problems during acceleration must await a more accurate description of these clinical observations.

Although it might seem reasonable to hypothesize that some static venous pooling occurs during forward acceleration, evidence presented here indicates that the possible reduction in effective circulating volume thus produced is not sufficient to impair either minute flow or stroke output at the levels investigated.

Changes resultant from postural repositioning, from the erect to the recumbent position at 1 G, result in some redistribution of the circulating blood volume from the greater to the lesser circulation.[3,11] Negative pressure breathing has been demonstrated to increase pulmonary blood volume.[13] Watson et al[18] have shown that forward acceleration simulates negative pressure breathing, and therefore may introduce an additional factor increasing pulmonary blood volume. Although definitive experimentation has not been performed it is reasonable to hypothesize that through a combination of these effects a greater fraction of the venous blood volume is now distributed to the lesser circulation.

Recent investigation[2] has demonstrated that a regional increase in pulmonary blood flow results in a decrease in vascular resistance in that region. Only careful investigation can confirm that this mechanism accounts for the normal total pulmonary blood flow (cardiac output) during forward acceleration in spite of obvious changes in perfusion of dependent lung areas.

A final word of caution must be imposed to prevent over simplifying the profound influence of centrifugal forces on the hydrostatic columns of blood which cause marked impairment of the flow distribution. No positional change can compensate for the pressure differential at high accelerations due to the A-P diameter of the body. In the dependent regions, since the body is essentially a fluid filled container, transmural vascular pressures are only elevated where counter support is lacking. Confirmatory evidence includes the presence of petechial hemorrhages over unprotected dependent skin regions in man, dependent frontal sinus hemorrhages observed in these animals, and redistribution of pulmonary blood volume as clearly demonstrated by human x-ray studies[7] and dog lung sections.[19] Recent clinical observations in this laboratory have been made of ischemic neuropathy after prolonged accelerations when subject's feet have been elevated somewhat more than 100 mm. above heart level. Since the major cardioregulatory mechanisms protect cerebral flow, special care must be taken to minimize this fall in pressure in less well protected regions.

SUMMARY

Chloralose anesthetized mongrel dogs were accelerated at 6, 10, and 14 G for ten-minute time periods, in the forward facing position, on the Wright Air Development Division centrifuge. Cardiac output, heart rate, circulation time, blood pressure, respiratory rate, and qualitative appearance of arterial blood were recorded.

Only minimal changes in cardiac output occurred. These changes correspond closely to decreases in heart rate, and increases in circulation time, resulting in unimpaired stroke output.

Blood pressure related to midchest surface anatomy fell slightly, but probably does not represent physiologically important alterations in the vital cardiac regulatory areas.

Respiratory frequency was increased and all arterial blood samples showed qualitative evidence of desaturation accompanied by marked clinical cyanosis of the mucous membranes.

The normal responses of the vascular system and of the heart as a pump in these experiments in no way contradicts concepts that marked changes occur in the distribution of blood flow. These changes are based on the physical dynamics of the hydrostatics and of the transmural pressure relationships in regions lacking adequate counter pressure.

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Human Tolerance to Whole Body Sinusoidal Vibration

Short-Time, One-Minute and Three-Minute Studies

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VIBRATIONS are phenomena well appreciated by military and commercial pilots. These forces have been high in frequency and low in amplitude characteristic of propeller systems. In recent years, there has been a shift to low frequency, high amplitude vibrations and buffetings due to the resulting aerodynamic forces produced by high performance jet propulsion systems. These forces are becoming disturbing factors in high speed low altitude flights and appear to be of vital importance in the launch and re-entry phase of rocket propelled, manned space vehicles. Criteria defining human limits of comfort, performance and safety in vibrational environments associated with various air and space craft missions are needed for the design and operation of such craft. It is also necessary for the flight surgeon to be aware of potential dangers resulting from anatomical and physiological alterations due to these extrinsically applied forces in order to maintain pilot and aircrew effectiveness.

The purpose of this study was to define human subjective tolerance to whole body sinusoidal vibrations between 1 and 20 cps. for short time, one and three minute periods. The frequency range and time periods were chosen for the following reasons: (1) buffeting and impact, loads as they occur in space vehicles and at high speed low altitude flights, have a frequency spectrum of this range and a duration of seconds or fractions of a second; (2) resonances of important body areas were found within this frequency range and body reactions to extrinsic forces are a function of time; (3) pilots can be easily protected against vibrations above 20 cps. by mechanical damping systems. For this study, tolerance is defined as the degree of vibratory stress human subjects are willing to undergo without obvious injury.

METHODS AND MATERIALS

A panel of ten members were assembled and included in the short time study. Five members were later added and a total of fifteen subjects were included in the one and three minute studies (Table I).

All vibrations in this study were sinusoidal in nature. A Western Gear mechanical shake table was utilized to attain frequencies ranging from 3 to 15 cps. The greatest amplitude obtain-

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From the Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Ohio.
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able is 22 cm D. A. The amplitude may be increased or decreased at a constant rate of 0.75 mm. D.A./sec. while vibrating at a given frequency.

TABLE I. VITAL MEASUREMENTS OF SUBJECTS

Subject	Age	Weight Lbs.	Height Ft.	Height In.
BW	32	195	6	0
CR	24	136	5	11
DF	23	200	6	1
EW	29	150	5	9
HR	34	200	5	10
LJ	25	143	5	7
ME	28	210	6	0
RE	29	145	5	7
RM	24	168	6	0
SR	27	197	6	3
Additional Subjects Included In the One and Three Minute Studies				
AA	21	150	6	1
GE	38	148	5	6
MD	29	130	5	7
SE	23	160	5	10
RR	31	199	6	1

At 1 and 2 cps. the amplitude necessary to reach tolerance could not be obtained on the shake table. Therefore, "the vertical accelerator" was used for these frequencies. This device can produce vertical sinusoidal motion with an amplitude of ±10 feet D. A. with an acceleration of ±3.5 G up to 7 cps.

The subjects were seated to simulate the position of a passenger in normal flight. A modified T-33 jet aircraft seat was mounted to the vibrating platform and the subject sat directly on a reinforced plywood board. With this, the true motion of the vibrating platform was transferred to the subject with a minimum of change. The subject sat with his coccyx firmly against the back of the chair and was firmly strapped in with a standard Air Force lap belt and shoulder harness. Care was taken to avoid serious impairment of respiratory movements and the mechanical characteristics of the abdomen and its contents were changed as little as possible. The seating arrangements were identical for all procedures. Electrocardiographic tracings were taken before, during and after each run.

The subject was able to grip the extended arm rests where a signal button was conveniently located. When the button was pushed, a buzzer signaled the operator to immediately stop the run.

PART I. SHORT TIME TOLERANCE

The frequency was preset and remained constant for each run. On the shake table the run began by starting at zero and increasing the amplitude at 0.75 mm. D.A./sec. Due to the large displacement at 1 and 2 cps., the vertical accelerator was used and the amplitude was increased at a constant rate of 10 mm. D.A./sec. When tolerance was reached, the subject pressed the buzzer button which signaled the operator to stop the run and at this point the amplitude was read. The maximum obtainable acceleration on the vertical accelerator at the time of this study was slightly under tolerance limits at 1 and 2 cps., therefore the subjects were asked how close they felt they were to their tolerance limits. Each rider estimated the possible increase of acceleration necessary to attain their tolerance. Accordingly, tolerance at these frequencies was empirically determined.

Prior to the study each subject was familiarized with the shake table and vertical accelerator and was given preliminary rides at various frequencies well below tolerance levels. It was made especially clear to the subjects that this study was attempting to define the limit of sinusoidal acceleration at various frequencies a rider would be willing to undergo before it was thought that actual body harm might occur. It was further emphasized that the limit of tolerance was not discomfort *per se*. Immediately following each run the subjects were asked to describe in detail the sensations which were the primary reasons for discontinuing the run. The criteria of tolerance for this study were subjective, hence, they were completely dependent upon sensations the subject might encounter.

RESULTS

The results are presented in Figure 1. They consist of the arithmetic mean, the standard deviation of the mean, and the extreme G values (vector) found for each frequency. The time in seconds to attain the mean acceleration is also included. The curves indicate a decreasing tolerance from very low frequencies up to approximately 4 cps. Minimal tolerance occurred between 4 and 8 cps. within the range of approximately 1.5 to 2.0 G. Above 8 cps. the magnitude of tolerable acceleration increases sharply, perhaps due to the increasing attenuation of the vibrations in the body.

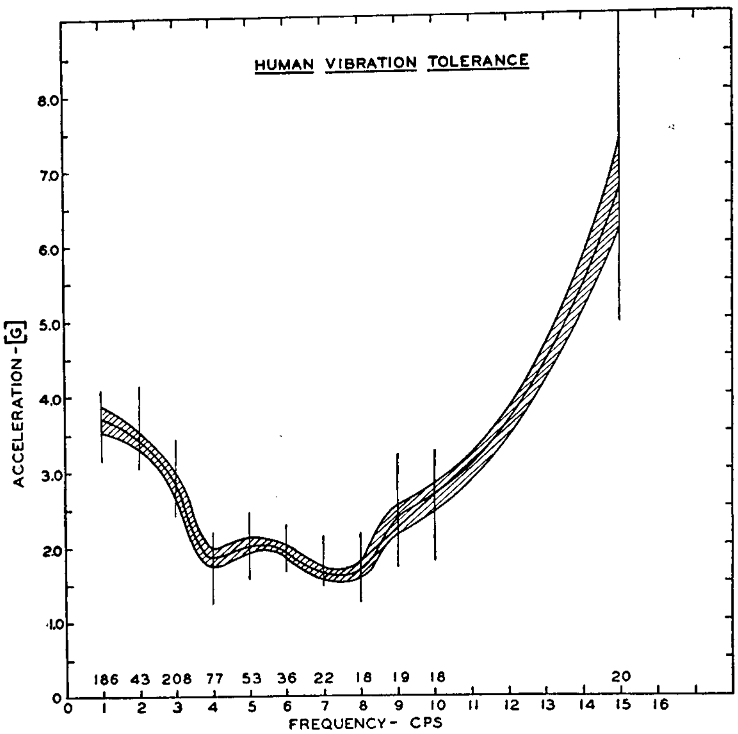

Fig. 1. Arithmetic mean, standard deviation, maximum deviation of tolerance values. Arithmetic mean of exposure time in seconds is indicated above the frequency scale for each test frequency.

Table II lists the specific sensations

or symptoms experienced during the study and given as reasons for attaining tolerance. Seven sensations are presented, four of which include pain

TABLE II. SYMPTOMS DEFINING TOLERANCE FOR SHORT TIME STUDY

Chest Pain: (Precordial)
Dyspnea: (Actual air hunger)
Abdominal Pain: (Peri-umbilical or lower mid-quadrant)
Testicular Pain: (Groin)
Head Symptoms: (Pain and/or congested sensation)
Anxiety: (Psychological response)
General Discomfort: (Summation of all symptoms in terms of discomfort)

referable to specific regions, that is, abdomen, chest, head and testicles. The pain distribution of the abdomen was about or below the umbilicus usually extending to the right lower quadrant. Chest pain had a distribution suggestive of the pain experienced in coronary heart disease; the pain occurred at the substernal of precordial area, frequently extending across the entire chest. The pain was never referred to the left arm or neck. The head symptoms were described as a dull, aching pain of low intensity or a full congested sensation. Testicular pain was described as being colicky in nature occurring at the groin. In general, the pain had a subtle onset and was dull, low grade in nature, increasing in intensity with crescendo-like characteristics.

Dyspnea and general discomfort had an onset similar to the painful sensations, a slow insidious onset building up to severe intensity. Respiratory movements were described as becoming impaired due to the superimposed movements of the vibrating platform on the physiological respiratory movements of the thoracic cage. General discomfort was described as an overall impression of the various rides; this included the sensations produced by muscles, joints, thorax and abdomen.

The preceding description demonstrates that the end point or tolerance level was attained well after the onset of the described symptoms and by continuing to run it was felt that body damage would occur. All sensations ceased immediately following the run except for the head sensations which tended to persist for several minutes.

One or more of these sensations were given by the subjects defining tolerance for a given frequency, however, only those sensations which were felt by the subjects to be clear-cut

TABLE III. SUBJECTIVE RESPONSE FOR DIFFERENT FREQUENCIES DURING SHORT TIME TOLERANCE STUDY

Each figure represents the total number of definite sensations or symptoms given as criteria for tolerance.

CPS	1	2	3	4	5	6	7	8	9	10	15
Chest pain			2	2	4	4	5	4	4	1	
Dyspnea	8	8	5	3							
Abdominal pain			2	2		3	2	1	2	1	
Testicular pain							1			3	
Head symptoms				2		1	1	1		2	
Anxiety			1	2	1			2		1	
General discomfort	3	4	5	5	6	4	1	3	5		8

were recorded. Table III contains a résumé of the sensations experienced for the frequencies investigated. The number of subjects experiencing each sensation is totaled for each frequency. This shows that four sensations predominated throughout the study; chest pain and abdominal pain were experienced between 3 and 9 cps., dyspnea between 1 and 4 cps., and general discomfort throughout the entire frequency range.

DISCUSSION

The stimulus produced by whole body vibration is the alternating displacement of organ systems and their supporting structures in relation to one another with subsequent tension and deformation. The transmitted mechanical forces, direction of force, anatomical configuration including body shape and size were the greatest variables of this study since the panel somatotypes ranged from thin non-muscular to medium muscular.

Subjective response determined tolerance for this study. The results were, therefore, dependent upon individual psychological reactions to conditions prevailing at the time of the run. Considering the variations inherent in subjectivity and differences in somatotypes, the spread of the tolerance curve is surprisingly small. This may partially be explained by the short exposure time at tolerance levels since the amplitude increased at a constant rate for all frequencies.

Seven sensations or symptoms are included in the criteria establishing tolerance levels. The sensations may be classified according to frequency (Table III) indicating that resonance of body parts plays a role in determining subjective response. This would be expected since the body exposed to vibrations reacts in the same manner as an inorganic system having lumped parameters. Knowing that the stimulus to vibration is relative displacement of tissue complexes, much insight may be gained into the mechanical dynamics of the body by evaluating the symptoms. The following is an attempt to define the etiology of the various symptoms encountered.

Abdominal Pain.—It is believed to be caused by stretching and deformation of the terminal ileum, cecum, hepatic flexure and transverse colon and of their supporting mesenteries.

Chest Pain.—Chest pain most commonly occurred between 5 and 9 cps. Displacement resulting in stretching of the major vessels originating at the base of the heart including the aortic arch is a probable source of pain. Also, mechanical stimulation by the vibrating heart on the diaphragmatic pericardium and the parietal pericardium about the base of the heart is another possible source of pain. Displacement of the diaphragm at its anterior attachments could produce chest pain, but this would be expected to be experienced about the sternum radiating outward bilaterally.

Testicular Pain. — Here pain is evoked by the alternating displacements of the spermatic cord and possible deformation of the testicles and surrounding tissues. The displacement necessary to elicit intense pain in these structures is very small because of their pain fiber distribution and characteristics.

Head Symptoms.—These are more difficult to evaluate. Part of the sensation is probably due to displacement of facial skin and subcutaneous tissues about the underlying bony structures. The role of the brain, spinal cord, cerebralspinal fluid and vasculature in the origin of the symptomatology must still be defined.

Dyspnea.—This occurred between 1 and 4 cps. and is the result of alternating displacements of the thoraco-abdominal system. Physiological respiratory movements were interfered with by the superimposed oscillating movements of the vibrating platform acting on the mass of the abdominal contents and the thoracic cage. Other possible factors contributing to dyspnea are possible changes in pulmonary hemodynamics such as pooling of blood in the pulmonary vessels resulting in pulmonary congestion.

Anxiety.—Anxiety was caused by a multiplicity of reasons among which pain, stimulation of the proprioceptive system and respiratory impairment played important roles.

General Discomfort.—This refers to an overall subjective response. Pain, respiratory difficulties, the sensations of rapid displacements of voluntary muscle groups and extremities including large joints, and vicera all were included in ascertaining a general impression for each frequency.

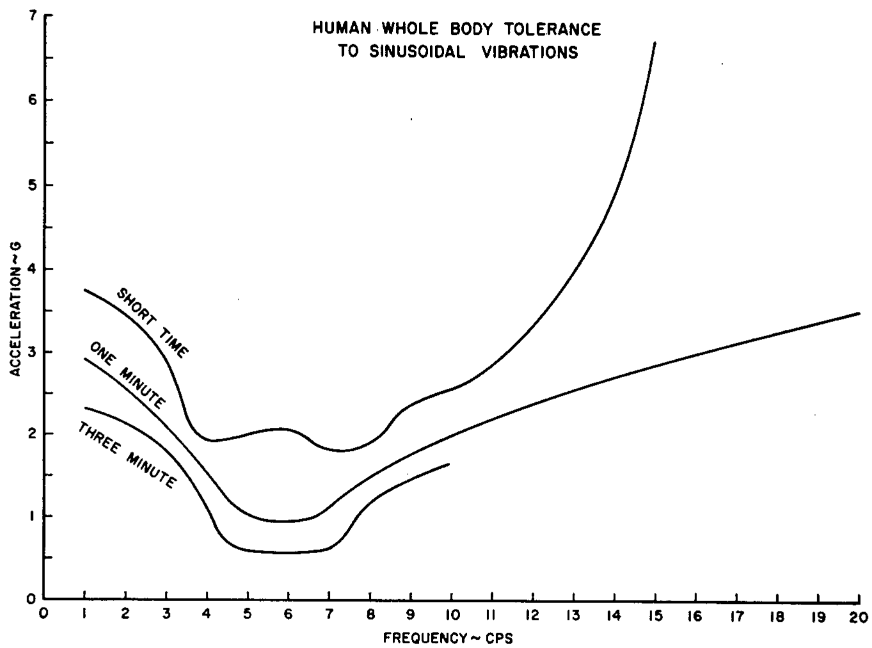

Fig. 2. Human tolerance to whole body sinusoidal vibrations.

PART II. ONE MINUTE AND THREE MINUTE TOLERANCE

A one and three minute period was investigated to ascertain human tolerance in the frequency range of 1 to 20 cps. and 1 to 10 cps. respectively. The seating arrangements and restraints were the same as utilized for Part I. Because of the severity of vibrations to which the subjects would be exposed for relatively long periods of time, it was decided to investigate the range of tolerance rather than attempt to define the actual tolerance for each subject. The original ten subjects and five additional subjects who were familiar with whole body vibration experiments were used in this phase of the study.

Accelerations for each frequency were predetermined during preliminary investigation. It was felt that the accelerations chosen for the one and three minute studies were well within the range of tolerance. The subjects were then exposed to all frequencies as previously described. After each run

TABLE IV. REGIONAL SYMPTOMATOLOGY

Head-Neck Head sensations Pharynx Jaw Speech
Thorax Respiration Dyspnea Pain Valsalva maneuver
Abdomen Voluntary abdominal contraction Pain
Pelvic Micturate (urge) Deficate (urge)
Skeletal Muscular Voluntary muscle contraction of extremeties Muscle tone Lumbosacral pain
General Discomfort

the subjects were asked to estimate approximately how much more G they could have withstood for the time period studied. During and following each run, subjective responses were recorded.

RESULTS

Figure 2 represents the results of the one-minute and three-minute tolerance studies along with the short time tolerance curve. The curves assume similar characteristics particularly between 1 and 10 cps. The greatest spread between them can be seen within the range of 3 to 8 cps.

Of the fifteen subjects in these studies, two could not complete 7 cps., one

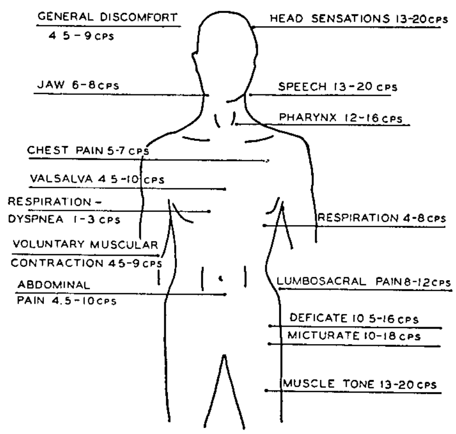

Fig. 3. Symptoms experienced for frequencies between 1 and 20 Cps. at tolerance levels.

could not complete 8 cps. and one 9 cps. for the three-minute series. For the one-minute series, two subjects could not complete 7 cps., and two could not complete 9 cps.

Sixteen different sensations or symptoms were elicited. They included those responses from the short time study with the exception of testicular pain and anxiety. Table IV shows a regional symptomatology compiled from these findings. Figure 3 shows the frequencies at which the various sensations were most acute.

DISCUSSION

The one-minute and three-minute studies afford an estimation of the upper limits of tolerance. At 4 to 8 cps. the tolerance was estimated to be approximately 0.25 G greater than the accelerations actually imposed. For the remaining frequencies the upper limits of tolerance were estimated to be approximately 0.5 G greater than the accelerations actually run.

The accelerations experienced during these studies were extremely severe. Little is known of their effects on anatomical and physiological integrity. Because of this modicum of understanding, true tolerance was not attempted but the extreme subjective responses suggested that the accelerations were well within the range of tolerance. Indeed, the subjective responses suggested several anatomical and physiological areas peculiar to low frequency, high amplitude vibrations that should be investigated.

Figure 3 shows that more than one sensation was experienced during these vibrations and that the threshold for different sensations varied with different frequencies. This figure also shows that at the lower frequencies the centrally located organ-tissue complexes are more affected, and as the frequency is increased, the peripherally located organs become affected to a greater extent. Generally, those organs having relatively large mobility and low resonant frequencies are centrally located and produce sensations at lower frequencies; conversely, those organs having relatively little mobility and higher resonant frequencies are peripherally located and produce sensations at the higher frequencies. This demonstrates that the sensations are freqeuncy dependent and that at least one etiological factor responsible for subjective response is the resonance of organ systems or subsystems.

Abdominal pain, chest pain, head symptoms, dyspnea and general discomfort have been discussed earlier. The possible etiological factors for these symptoms are the same for the long term studies. The remaining symptoms are discussed.

Jaw.—The mandible and its surrounding soft tissues apparently resonate between 6 and 8 cps.

Pharynx.—The sensation of the pharnyx is described as a "tug" or "lump" in the throat quite similar to "globus hystericus." Apparently, resonance of the trachea and possibly main stem bronchi occurs at these frequencies and the sensations are the result of the trachea mechanically stimulating the sensory receptors of the supporting pharyngeal tissues.

Speech.—At the lower frequencies speech is secondarily affected by the mechanical reactions of the thoraco-abdominal system. At the higher frequencies the superimposed transmitted vibrations to the trachea, particularly at the laryngeal area and possibly to the main stem bronchi, have a greater detrimental effect upon phonation.

Pelvis.—Between 10 and 18 cps., the subjects experienced a severe urge to micturate, and between 10.5 and 16 cps. a severe urge to defecate. Prior to each run the subjects were instructed to empty their bladders and defecate if possible so that at the beginning of a run the pelvic organs were relatively empty. Following the run, the urgencies immediately subsided. Stretching and deformation of the walls of these potentially hollow organs, perhaps due to resonance, stimulated the sensory receptors within their walls.

Voluntary Muscular Contraction.—Voluntary muscular contraction reached maximum intensity between 4.5 and 9 cps. At these frequencies the subject has a tendency to bounce with relation to the seat regardless of the security of the lap belt and shoulder straps. The abdomen, thorax and extremeties are alternately forcibly displaced. The subject attempts to compensate by grasping the seat handles and simultaneously the lower extremities are forced down against the vibrating platform.

Muscle Tone.—Between 13 and 20 cps., the subjects experience an involuntary "tightening" sensation of the lower extremities, back, neck and head. It is suggested that at these accelerations the transmitted force and perhaps resonances of the skeletal musculature increase the mechanical stimulation of the myotatic receptors thereby increasing muscle tonus.

Lumbosacral Pain. — Lumbosacral pain was most intense between 8 and 12 cps. The pain was moderate to severe, occurring at the lumbosacral area, and is probably the result of exaggeration of the physiological lordotic configuration of the region and possible compression of the intervertebral tissues. The pain subsided immediately following the run.

Valsalva Maneuver.—A partial or complete valsalva maneuver was performed with reflex-like characteristics and was of greatest intensity between 4.5 and 10 cps. This coincides with the frequencies having the greatest effect upon the abdomen and thorax. This maneuver increases positive pressure within the thorax which is transmitted to the abdominal compartments. This has the effect of stiffening the walls of these compartments thereby compressing the viscera. By performing this maneuver, displacement of the viscera is minimized thereby affording protection to the alternating forces.

Respiration.—The subjects stated that the superimposed passive oscillations of the thoracic cage and diaphragm upon the physiological respiratory movements interfered most between 4 and 8 cps. This sensation did not include dyspnea.

Electrocardiographic tracings were taken before, during and after each frequency run. No abnormal tracings were encountered except in one case. The subject had finished a one-minute run at 8 cps. He stated that he did not feel well, became light headed, disphoresed and almost lost consciousness. Pulse and blood pressure could not be obtained. This was transitory and the subject quickly recovered. The ECG showed inverted P waves with nodal tachycardia which lasted for approximately two minutes. The P waves then became upright and the ECG resumed its normal pattern.

Precordial pain, interference with respiration and valsalva maneuver could have possible deleterious effects due to long time exposure to vibration particularly within the range of tolerance. At the end of each run, which included four to six frequencies, the subjects experienced facial flush and, following this, most subjects disphoresed and were euphoric. Two to four hours later most subjects experienced weariness and for several hours became somewhat depressed. These findings suggest alterations in metabolic and hormonal secretions during and following the runs.

The technique of obtaining subjective response is another method which may be used to define certain mechanical reactions of the body to extrinsic whole body vibrations. This is best illustrated by comparing the investigations of the thoraco-abdominal system[1,2] with the subjective responses. Resonance of the thoraco-abdominal system was mechanically measured and found to be within the range of 3 cps., but the most intensive abdominal pain was experienced between 4.5 and 10 cps, and chest pain between 5 and 7 cps. Although the mechanical measuring techniques defined the overall resonance of the thoraco-abdominal system, the subjective response technique suggested that resonances of the subsystems could be identified.

SUMMARY

Short time, one-minute and three-minute tolerance studies were performed. Ten subjects were included in the short time studies and a tolerance curve based on subjective responses was compiled. Because of the danger of incurring actual body damage, the tolerance range was attained and the actual tolerance level estimated for the long time studies, in which fifteen subjects were included.

Sixteen sensations or symptoms were recorded and a table describing regional symptomatology was compiled unique to low frequency, high amplitude sinusoidal whole body vibrations within the range of subjective tolerance. The possible etiology of the symptoms experienced during vibration are discussed.

ECG was taken before, during and after each run. No abnormal tracings were observed except in one case. After a one-minute run at 8 cps., the subject experienced momentary syncope associated with inversion of the P wave and a nodal tachycardia. The syncope was transitory and the P wave reverted after two minutes with no sequelae.

It is suggested that subjective response may be utilized to aid in defining mechanical and physiological reactions of the body to vibrations.

Further study is necessary to ascertain the dynamics of the cardiovascular system, pulmonary system, nervous system, skeletal musculature and internal secretions during low frequency, high amplitude whole body vibration.

ACKNOWLEDGMENTS

The authors are indebted to Mr. Richard D. Lowry for installation and operation of the electronic equipment for the vertical accelerator and shake table and for development of an electrocardiograph to take readable tracings during vibration. We are indebted to Master Sergeant William J. Bosley for his ingenuity in mounting the equipment on the vibrating platform and maintenance and operation of the vertical accelerator and shake tables during the experimental procedures.

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The Ballistocardiographic and Plethysmographic Response of "Normal" and Cardiac Patients to Nitroglycerin

LOUIS R. KRASNO, M.D. and GEORGE J. KIDERA, M.D.

SINCE 1877, when J. W. Gordon obtained the first "crude" recording of the response of the body to cardiac activity, considerable effort has been expended to develop highly sensitive instrumentation and standardize the ballistocardiogram for application in clinical medicine. Unfortunately these objectives to a considerable extent, remain to be attained. Not all investigators in this field are in accord with regard to what constitutes the best instrumentation, procedure, and standards of normality. Nevertheless ballistocardiographers believe that this method of measuring cardiac function has great potential value and will be applicable in clinical medicine when a number of basic variables are controlled. On the other hand there are those who believe that the biophysical variables inherent within the body can not be overcome and therefore the reliability and validity of this procedure will be impossible to establish. It is not the purpose or within the scope of this presentation to discuss the known variables in ballistocardiography. However, some of these factors should be at least pointed out. They are: (1) The transmission of cardiac forces internally within the body. (2) The natural frequency of the body which set up "parasitic" oscillations and tend to mask the cardiovascular complexes. (3) The hemodynamics of the circulation in the same patient at different times and in different patients. (4) Compliance of tissues between heart and skeletal system and between skeletal system and the structure supporting the body, i.e., the bed. (5) Ambient vibrations originating external to the circulation and body. (6) The instrumentation, particularly the type of bed support.

It immediately becomes apparent that many of the biophysical factors such as circulatory hemodynamics, tissue compliance, transmission of cardiac forces internally, etc., are rather inaccessible and difficult to control or evaluate. For example, it would not be reasonable to expect an obese man, age twenty-five, weighing 225 pounds, 5 feet 7 inches tall to yield a ballistic pattern identical to that of a non-obese individual of the same age, but 6 feet 2 inches tall, weighing 175 pounds. The fundamental difficulty in ballistocardiography has been the standardization and interpretation of the response on an absolute basis in a cross section of population in whom there

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are naturally occurring wide variances in biophysical factors.

The purpose of the present report is twofold: (1) To describe a technique which permits the biophysical factors within and physical factors extraneous to the body to remain essentially constant during which time certain hemodynamic changes are transiently induced. (2) An attempt to physiologically identify the arteriosclerotic process by this procedure.

METHODS

The hemodynamic changes were induced by the administration of 0.0004 gms. of nitroglycerin sublingually. Two basic groups of individuals were selected for purposes of interpreting, standardizing, and validating the ballistocardiographic response to nitroglycerin. One group consisted of 354 normal individuals who, as far as was known, were free of cardiovascular disease. A second or abnormal group consisted of sixty-four individuals known to have angina pectoris (twenty-seven), previous myocardial infarction (fourteen), essential hypertension (seventeen), right bundle branch block (two), and left bundle branch block (four). Angina pectoris was existent from ten months to nine years. The myocardial infarctions had occurred from six months to seven years previously. The age range of those individuals with myocardial infarction and angina pectoris was from thirty-three to sixty years. The age range of both the abnormal and normal group was from twenty-one to sixty-four years. Sixty individuals were thirty years old or younger and five individuals were sixty-one years old or older. The normal group of 354 consisted of 127 individuals with positive family histories of heart disease. The normal group also consisted of twenty-nine individuals with hypercholesterolemia. A baseline ballistocardiogram was compared with the response due to the induced hemodynamic alteration, all of which is obtained within a matter of minutes. The interpretation was then based on relative changes occurring in the same individual over a period of minutes, rather than on an absolute basis involving different individuals.

The instrumentation consisted of a four-channel Sanborn direct-writing oscillograph, a Smith-Perl transducer and a rigid floor type bed support (high frequency). A digital plethysmograph was used to "monitor" the ballistocardiogram. The plethysmograph used in this study was a photoelectric cell-transistor type recording peripheral pulse volume. The plethysmograph was used as a "monitor" in place of the electrocardiogram in order to observe whether there would be a differential plethysmographic response to nitroglycerin in normal persons and those having coronary artery disease, hypertension, or conduction defects.

The procedure consisted of allowing the individual to rest in the recumbent position for twenty minutes. A baseline ballistocardiogram was obtained and then 0.0004 gms of nitroglycerin was administered sublingually. The ballistocardiographic response was recorded every four minutes for twelve minutes thereafter. If no decrement or increment occurred in the HI or IJ waves in the displacement, velocity and acceleration curves within the first twelve minutes, a second nitroglycerin tablet was administered and recordings were obtained again every four minutes for a period of twelve minutes. If no change occurred during the second twelve minutes the response was considered to be "fixed." All recordings were obtained during suspended inspiration and expiration.

This procedure was repeated four times at intervals of seven to ten days on all 27 persons with angina pectoris, on 10 persons with myocardial infarction, and on 10 persons with hypertension in order to establish the reliability of the observations in the abnormal group.

RESULTS

It became readily apparent that the ballistocardiographic and plethysmographic response to nitroglycerin (BNR and PNR) in persons known to have coronary artery and hypertensive disease was basically different than that observed in individuals without these abnormalities. In the abnormal group the BNR (ballistocardiographic response to nitroglycerin) was either typically "fixed" or showed characteristic decremental changes in which the HI and IJ waves in the displacement, velocity and acceleration curves decreased below that established in the baseline graph (Fig. 1). On the other hand, in the "normal" individuals the BNR showed typical incremental changes or an increase in the HI and IJ in the displacement, velocity and acceleration curves (Fig. 2). A certain number of presumably normal individuals also showed a decremental or "fixed" response. The plethysmographic response to nitroglycerin or the PNR was basically of two types. The PNR may show a substantial increase in the ascending limb of the pulse volume curve with a severe displacement of the dicrotic notch to or below the baseline. On the other hand, the PNR may remain relatively "fixed" showing very little of the aforementioned changes. The PNR or plethysmographic response to nitroglycerin was variable. The variability of the PNR will be discussed further.

The results are presented in Table I. The BNR was decremental in 5 or 18 per cent and fixed in 22 or 82 per cent of the individuals with angina pectoris. The BNR was decremental in 2 or 14 per cent, incremental in 1 or 6 per cent and fixed in 11 or 80 per cent of the individuals with myocardial infarction. The two individuals with decremental and 1 individual with incremental BNRs have been on sustained anticoagulant therapy. The plethysmograms were relatively "fixed" in 72 per cent of individuals with angina pectoris and in all patients with myocardial infarction.

The BNR was decremental in 12 or 70 per cent and fixed in 5 or 30 per cent of individuals with essential hypertension. Incremental PNRs were present in those having decremental BNRs and relatively fixed PNRs were present in those having fixed BNRs.

The BNR was decremental in one out of the two persons with right bundle branch block and in three out of the four persons with left bundle branch block. The plethysmograms were incremental in all individuals with intraventricular conduction defects. Twenty-one or 72 per cent of normal individuals with hypercholes-

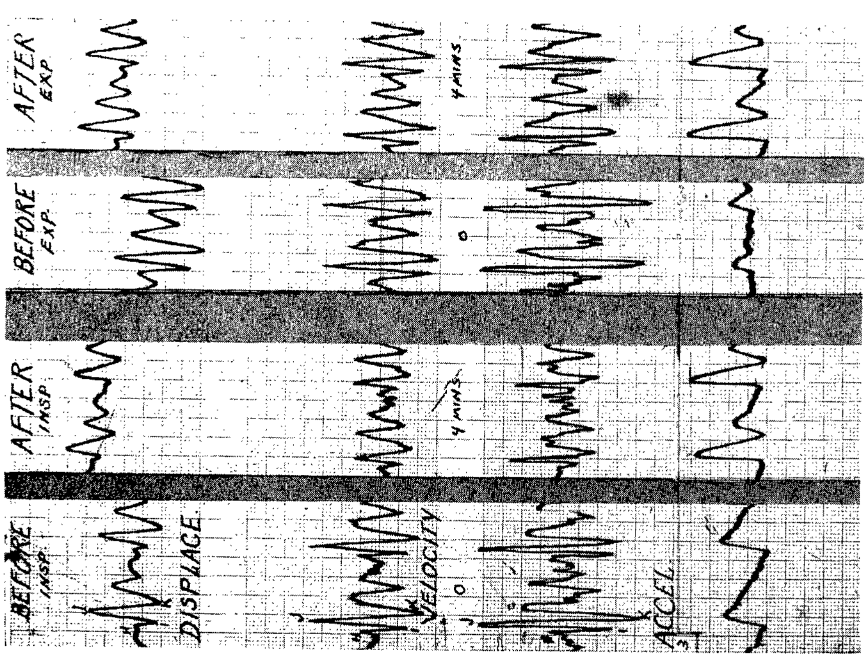

Fig. 1. Ballistocardiogram in a thirty-year-old man with essential hypertension. HI and IJ waves decrease during suspended inspiration and expiration following nitroglycerin.

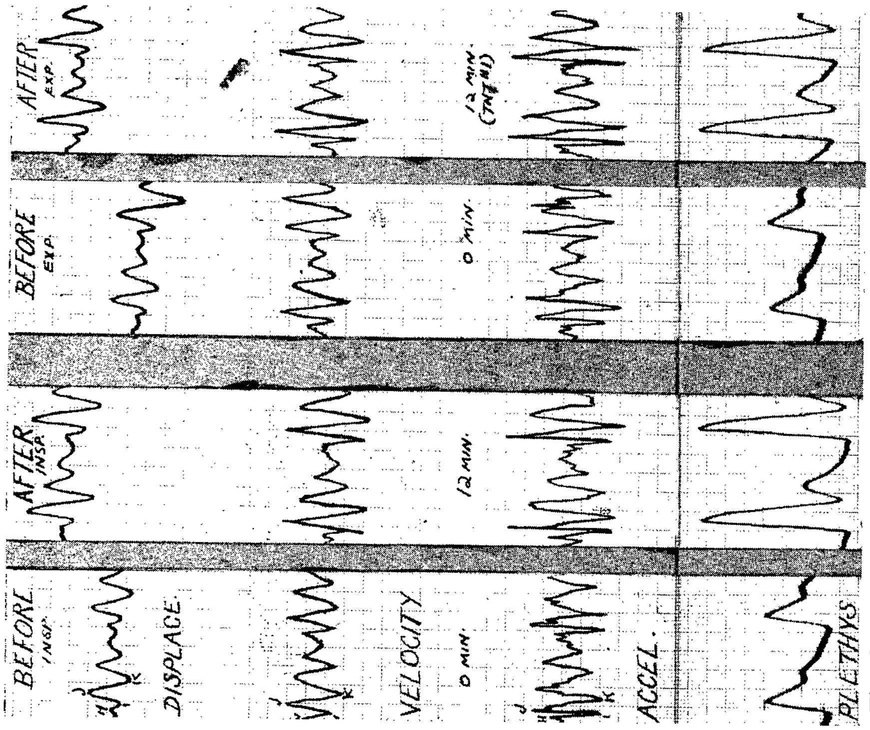

Fig. 2. Ballistocardiogram in a normal twenty-nine-year-old man. HI and IJ waves increase during suspended inspiration and expiration following nitroglycerin.

terolemia had "fixed" BNRs. The decremental and "fixed" BNRs were completely and repeatedly reproducible on all individuals in the abnormal decremental or fixed BNRs were above age 35. Forty-four per cent of the normal individuals with incremental BNRs were above age 35 (Fig. 3).

TABLE I. SUMMARY OF RESPONSES OF NORMAL AND ABNORMAL SUBJECTS TO NITROGLYCERIN AS SEEN IN THE BALLISTOCARDIOGRAM AND PLETHYSMOGRAM

	Normal Group	Abnormal Group (64)					Normal Hyper-Chol.
		Myocard. Infarct.	Angina Pectoris	Hyper-tension	RBBB	LBBB	
Number Individuals	354	14	27	17	2	4	29
Type of Response							
I. Increased BNR	209 (59%)	1 (6%)			1 (50%)	1 (25%)	6 (22%)
a. Increased PNR	187				1	1	5
b. Rel. fixed or decreased PNR	22	1					1
II. Decreased BNR	131 (37%)	2 (14%)	5 (18%)	12 (70%)	1 (50%)	3 (75%)	21 (72%)
a. Increased PNR	42		4	12	1	3	8
b. Rel. fixed or decreased PNR	89	2	1				13
III. Fixed BNR	14 (4%)	11 (80%)	22 (82%)	5 (30%)			2 (6%)
a. Increased PNR	4		2				0
b. Rel. fixed or decreased PNR	10	11	20	5			2

group. In a number of instances the basic response has been altered by various therapeutic agents such as anticoagulants, diuretics and vasodilators.

Two hundred nine or 59 per cent of "normal" individuals had incremental BNRs. One hundred thirty-one or 37 per cent of normal individuals had decremental BNRs and 14 or 4 per cent of normal individuals had "fixed" BNRs. Of the 14 normal individuals with fixed BNRs, nine had positive family histories of heart disease. The plethysmogram was relatively fixed in only ten per cent of normal individuals with incremental BNRs but in 68 per cent of normal individuals with decremental BNRs and in 71 per cent of individuals with fixed BNRs. 71 per cent of the normal individuals with

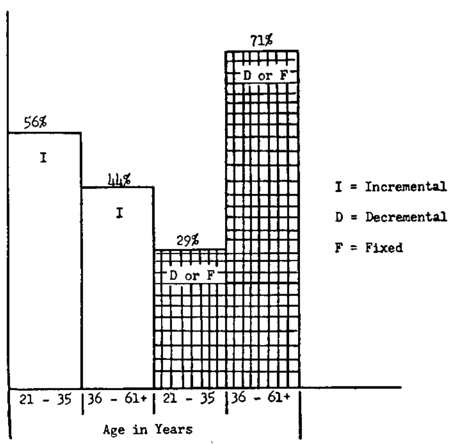

Fig. 3. Ballistocardiographic response to nitroglycerin according to age.

DISCUSSION

This study preliminarily reveals a high degree of correlation between myocardial infarction, angina pectoris, hypertension, hypercholesterolemia, and aging with a characteristically "fixed" or decremental response of the ballistocardiogram to nitroglycerin. The alteration of the fixed BNR by various therapeutic agents (anticoagulants, diuretics, vasodilators) offers further corroborative evidence of this correlation. The question is raised therefore as to whether a response of this type in otherwise normal individuals represent a subclinical phase of arteriosclerotic pathogenesis or is indicative of the "physiological aging" process, or whether it is, up to a point, both. In an attempt to answer this question, the following studies are being undertaken: (1) All normal individuals with abnormal BNRs and PNRs will be followed on a long term basis to determine whether the character of the BNR and PNR is altered and/or if clinical and laboratory evidence of arteriosclerotic disease becomes ultimately apparent. (2) To quantitatively measure the ballistocardiographic changes occurring following the administration of nitroglycerin and relate them to the initial record preceding nitroglycerin as well as to the age of the individual. It may be possible to develop quantitative standards by which physiological and pathological responses can be differentiated at various age levels. (3) In addition, further observations on the effect of various therapeutic agents on the BNR and PNR will be studied to determine whether this procedure may assist in gauging the efficacy of therapy as well as validating the procedure as a measure of arteriosclerotic heart disease.

A second question to consider is the mechanism by which nitroglycerin renders the differential response in abnormal and normal individuals.[3] Nitroglycerin is known to act on the arterioles, capillaries and venules with the most marked effect being on the post-arteriolar vascular bed. It diminishes both heart volume and stroke volume secondary to a decrease in venous return.[2,6,8] The ultimate ballistocardiographic response to nitroglycerin appears therefore to be determined by the relative degrees to which stroke volume and peripheral resistance are reduced.[2,4,5] It is believed that in the normal individual peripheral resistance is reduced to a greater extent than is stroke volume by nitroglycerin, and as a consequence the HI and IJ ballistocardiographic response particularly in the velocity and acceleration curves are enhanced.[1,7] In the arteriosclerotic individual it appears that stroke volume is reduced to a relatively greater extent than is peripheral resistance and therefore the ballistocardiographic response shows either a fixed or decremental change. The same basic explanation may be applied to the plethysmogram. The variability in the plethysmogram may be explained by the relative effects of nitroglycerin on the visceral blood vessels as compared with the blood vessels of the extremities at which point the plethysmograph records.

Although the number of individuals with bundle branch blocks were small, the decremental BNRs obtained in these instances warrant further investigations with this procedure in intraventricular conduction defects as a possible means of determining associated organic heart disease.

SUMMARY

A new technique physiologically identifying the possible presence of an early arteriosclerotic process based on relative changes occurring in the ballistocardiogram and plethysmogram following the hemodynamic response to nitroglycerin is described. The increased validity of this procedure due to the control of biophysical and physical variables is indicated.

Certain arteriosclerotic diseases as myocardial infarction, angina pectoris and hypertension are identified with a "fixed" or decremental response of the HI and IJ waves of the ballistocardiogram following nitroglycerin. Persons with myocardial infarction showed 80 per cent fixed, 14 per cent decremental, and 6 per cent incremental BNRs. Individuals with angina pectoris showed 82 per cent fixed and 18 per cent decremental BNR responses. The BNRs in hypertensive individuals were 30 per cent fixed and 70 per cent decremental.

A decremental response in the BNR occurred in 37 per cent and a "fixed" response in 4 per cent of otherwise normal individuals. Further quantitative analysis of these records has been initiated in an attempt to differentiate between "physiological" and "pathological aging" of the blood vessels in individuals without evidence of clinical heart disease.

Seventy-two per cent of individuals with hypercholesterolemia were identified with decremental BNRs whereas 6 per cent of these individuals had "fixed" BNRs. The latter two individuals had blood cholesterols of 460 and 436 mgs. per cent.

Seventy-one per cent of the normal individuals with decremental or fixed BNRs were above age thirty-five. Forty-four per cent of the normal individuals with incremental BNRs were above age thirty-five.

One of two individuals with right bundle branch block and three of four individuals with left bundle branch block showed a decremental BNR. The need for further observations on a large series of individuals with intraventricular conduction defects is indicated. The possible usefulness of this procedure in evaluating the presence of associated organic heart disease in this type of cardiac defect is indicated.

Attention is called to the possible usefulness of the BNR and PNR in gauging the effectiveness of therapy. Reference is made to the normal BNR in one individual and the decremental BNR in two individuals with myocardial infarction who have been on sustained anticoagulant therapy.

The variability in the plethysmogram is believed to be due to the relative degree of peripheral resistance in the blood vessels of the extremities as compared to that in the viscera.

The relative changes in peripheral resistance and stroke volume following nitroglycerin is offered as a possible explanation for the differential ballistocardiographic and plethysmographic response in normal individuals and those with coronary artery disease or hypertension.

ACKNOWLEDGMENT

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After Medical School

What happens to medical school graduates after they complete their formal education? The Harvard Medical Alumni Association recently assembled a composite portrait of approximately 1,000 living physicians who graduated from the school over a forty-five-year period.*

Biographic findings:

Principal Fields of Practice. Surgery, 300; internal medicine, 297; general practice, 65; pediatrics, 64; psychiatry and neurology, 54; obstetrics and gynecology, 50; ophthalmology, 20; pathology, 20; radiology, 17; urology, 14; otolaryngology, 10; anesthesiology, 8; dermatology, 7.

Residence. Graduates have established practices in all but four of the 50 states, including Massachusetts, 292; California, 96; New York, 94; Connecticut, 45; Ohio, 40; Pennsylvania, 32; Washington, 25; Texas, 24; North Carolina, 23; Michigan, 22 and Maine, 20; fifteen are practicing in foreign countries.

Marital Status. Nearly 900 of those reporting their marital status are married, only 54 are single.

Children. Average number of children is 2.63 or slightly above the national average. Listed are 1,235 sons, 1,105 daughters and 512 grandchildren.

Medical Offspring. At least 47 of the children have either received their medical degrees or are presently enrolled in medical schools. Seven received their M.D. degrees from Harvard and three are now students there.

*Classes of 1910, 1915, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1955.

From *MD,* August, 1960

Calorie Neutralization during Thermal Stress

CAPTAIN JOSEPH GOLD, USAF, MC

THE PRIME effect of thermal stress is the absorption of calories which, if allowed to accumulate, results in the progressive deterioration (to the point of total incapacitation) of a subject's ability to perform. Because even a small decrease in the net absorbed calories could be beneficial, it was decided to investigate the possibility of neutralizing some of these absorbed calories by the administration of cold fluids to the subject. It was thought that since the difference between ability and disability to perform in heat may be a matter of only several calories, decreasing the net absorbed calories may result in extending the time of usefulness during heat exposure.

Accordingly, two methods of fluid administration were employed: (1) the dispensing of body temperature water (37° C); and (2) the dispensing of ice water (0° C). The former method, known as sweat replacement, was designed merely to replace the amount of body water lost during a typical heat run, the idea being that perhaps increased sweating might occur, leading to the dissipation of more calories through evaporative cooling. The latter method, here known as calorie neutralization, in addition to making available more sweat for evaporative cooling, was designed to neutralize some of the calories absorbed from a hot environment during thermal stress. It will be noted that for every gram of water at 0° C. taken into the body, 37 small calories must be expended to lift it up to body temperature; these calories come from the body and can be considered obligatory. Every gram of water administered at 0° C., therefore, will necessarily neutralize 37 calories.

Neither of the foregoing methods is new. In 1939, Lehmann[11] suggested that during work at high temperature enough liquid should be taken in to replenish sweat loss. In 1944, Ladell[9] et al. advised that under climatic conditions of 115° F. and 15 per cent relative humidity, preventive methods for hyperpyrexia "should include the education of men to drink enough fluid to give at least thirty ounces of urine per day." However, whether replacing sweat loss alters the sweat rate is still a moot question. In a later article, Ladell[10] suggests that drinking water in excess of the sweat loss does not alter the sweat rate. Indeed, it is universally accepted that since sweating is regarded as a regulatory, not metabolic, process, it is not influenced at all by water intake. But as Kuno[8] points out, there may be par-

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ticular conditions when "an intake of water may sometimes, though not always, [increase] sweating considerably." We have found this to be the case also.

As recently as 1959 Benzinger,[1] engaged in calorie neutralization studies for the purpose of ascertaining sudomotor effects, found that eating 450 grams of an ice water emulsion caused the internal temperature to drop by about 0.6° C., reaching a minimum after approximately ten minutes, and then swiftly returning to normal; with the depression of internal temperature a concomitant depression of sudomotor activity ensued, resulting in a rise in temperature of the drying skin.

Sweat replacement and calorie neutralization studies, however, have never been carried out as controlled procedures for examining effects on: body heat storage (q_s); effective body heat storage* (q_e).[5]; the Modified Craig Index of Strain (I_s)[4]; and the newly developed Accumulative Circulatory Strain Index (I_G).[6] It was decided to embark on these studies in the present paper, to see whether their effects might result in increased exposure time to heat.

METHODS

The environmental test facility (All Weather Room) is capable of maintaining steady state ambient temperatures from 30° F. to 190° F., in combination with any level of relative humidity. Experiments were carried out at two levels—130° F. (54.4° C.) for two hours, and 160° F. (71.1° C.) for one hour—each at a vapor pressure of 10 mm. Hg (relative humidity of 8 per cent and 4 per cent, respectively).

Body heat storage (q_s) was calculated by the method of partitional calorimetry[2,3]—from experimental results yielding the average increase in body temperature in degrees centigrade. This figure is obtained by the use of special underwear containing seventeen thermistors which press upon various areas of the subject's skin; temperatures from these areas are automatically recorded on a Brown Potentiometer, together with rectal temperature. Figures for the increase in average skin temperature and in rectal temperature thus obtained are weighted two-thirds rectal/one-third skin, to yield an overall increase in average body temperature. This latter figure, multiplied by the specific heat of the body (0.83) and kilogram body weight, yields the number of Calories absorbed. Body surface area in square meters is obtained from standard weight-height nomograms. Dividing caloric uptake by surface area, yields Calories per meter square body surface; dividing this figure by time, yields Calories per meter square body surface per hour (q_s).

Effective body heat storage (q_e) is obtained from a theoretical treatment of body heat storage.[5] As such it is a measure and mirror of the body's heat-dissipating abilities.

The Modified Craig Index of Strain (I_s) is as follows:

*Effective body heat storage is defined as that amount of storage obtained (in Calories per meter square body surface per hour) if the subject were able to walk into the heat chamber already fully equilibrated with the hot environment, and with all heat-dissipitating mechanisms fully operating.

I_s = H/100 + T + S, where
H = the terminal heart rate
T = the rise in rectal temperature in degrees C per hour
S = the sweat production (nude weight loss in kilograms per hour).

The Accumlative Circulatory Strain Index (I_G) is obtained from a theoretical development of heart rate.[6] It was formulated upon the three following foundations: (1) that it contain a provision for initial as well as terminal heart rate; (2) that it contain a provision for the treatment of common increases in heart rate at different initial levels; and (3) that it correspond to physiological reality. The necessary measurements for obtaining I_G are only two: beginning and ending heart rate. An accurate and reliable cardiotachometer is recommended for this purpose.

In addition to the thermistor underwear the subject is clothed in a light flying suit and ordinary shoes and socks. Total clo value is approximately 1.0.

The subjects were maintained in the environmental test facility in a sitting, resting state. In the sweat replacement studies they were given 1000 ml. of 37° C. water over a period of an hour in five equal (200 ml.) installments, or over a period of two hours in ten equal (100 ml.) doses. Exceptions to this were subjects A and C; the former was given 1100 ml., the latter, 1500 ml. In the calorie neutralization experiments, all subjects were given 1000 ml. of 0° C. water over one or two hours, depending on the type of experiment; 200 ml. of ice water were distributed to the subject every twelve minutes in the one-hour runs, and 100 ml. were given every twelve minutes over the two-hour runs.

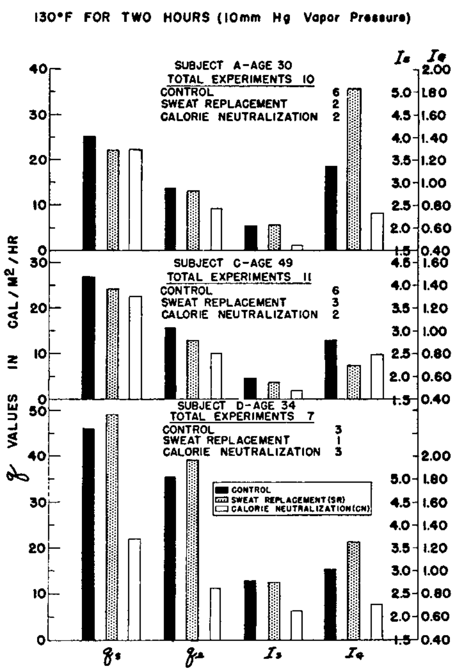

Fig. 1. Exposure of three subjects to 54.4°C. (130°F.) and 10 mm. Hg. vapor pressure for two hours (twenty-eight experiments in all).

RESULTS

Results of the 130 degree exposures are shown in Figure 1. Twenty-eight experiments in all were performed on three subjects—aged 30, 34, and 49. Calorie neutralization (CN) experiments showed significantly lower q and I values in all three subjects. Control q_s values varied between 25.0 and 46.4 Cal/m²/hr, whereas their corresponding CN values ranged between 21.9 and 22.3. Control q_e values varied between 13.5 and 35.4, whereas their CN values were between 9.2 and 11.4. Sweat replacement (SR) studies showed no consistent tendency, but their results can nevertheless be interpreted. It was interesting that the q_s values for CN are very nearly the same (21.9, 21.9, and 22.3), whereas this was not so in the control and SR studies; also the q_e values for CN were nearly the same (9.2, 10.3, and 11.4), whereas again their control and SR comparisons were not. The significance of this is discussed below.

Subject D, the victim of several diseases including epithelioma, "jungle rot," duodenal ulcer, and overweight, was found to have unusually high q values in both the control and SR studies; this was attributed to his difficulty in sweating. However, only in the CN runs did he sweat normally, as evidenced by the low q values in these experiments.

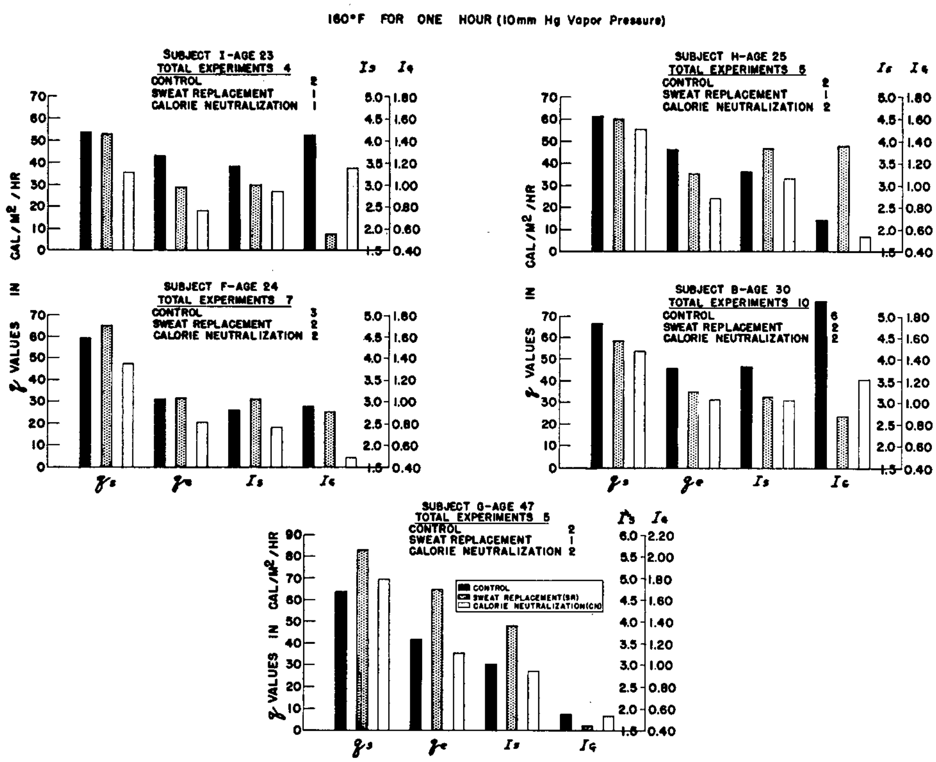

Fig. 2. Exposure of five subjects to 71.1°C. (160°F.) and 10 mm. Hg. vapor pressure for one hour (thirty-one experiments in all).

Results of the 160 degree runs are shown in Figure 2. Thirty-one experiments in all were performed on five subjects aged 23, 24, 25, 30, and 47. Lower q and I values were obtained in all CN experiments (with the exception of the q_s value for subject G); and again SR studies showed a variable response. Control q_s values varied between 53.6 and 63.3 Cal/m²/hr, whereas corresponding CN values ranged between 37.4 and 69.0; control q_e values varied between 31.2 and 47.4, whereas CN values were again low—between 18.9 and 36.5. SR values were intermediate.

DISCUSSION

The ingestion of 1000 ml. of ice water should normally deprive the body of 37 Calories. However, this need not be so. In some subjects however such an intake will impose an excess burden on the circulatory system causing it to work less efficiently in its effort to dissipate heat and hence less than 37 Calories might be neutralized. In other subjects the ingestion of a liter of water might make available more sweat for evaporative cooling and thus more than 37 Calories might be neutralized. It must be realized however, that the measurements in this paper were obtained through the use of partitional calorimetry so that inaccuracy in the absolute measurement of neutralized calories are bound to appear. Nevertheless, this system has proved accurate enough to yield reproducible and reliable data.

It will be noted in Table I that in the 130 degree experiments both subjects C and D had increased sweating due to calorie neutralization. In the case of subject C (age 49) the increased sweat production amounted to 144 grams; with subject D (age 34) the increase was 272 grams. Note (Fig. 1) that in subject C the indicated amount of effective Calories (q_e) neutralized (when corrected for time and body surface area) is 19.4. But in case D it is 98.9, a figure far greater than the theoretical 37. How can one account for this?

It will be remembered that subject D did not sweat readily and his sweat production approached the limits of normal only under conditions of calorie neutralization. This is borne out in Table I. Subject D's increased sweat production was 272 grams. His E/S (Evaporative/Sweat) ratio was 0.70. Therefore the increased amount of evaporated sweat was about 190 grams. Since the heat of vaporization of water is 540 calories per gram, this amounts to 102,600 calories, or 102.6 Calories. Assuming that half the heat needed for evaporation of excess sweat came from the subject (high skin temperatures) one could account for 51.1 Calories in addition to the theoretical 37 from the ingestion of a liter of ice water. The sum of the

TABLE I. SWEAT RESPONSE DURING CONTROL, SWEAT REPLACEMENT, AND CALORIE NEUTRALIZATION EXPERIMENTS

Subject	Kind of Experiment	Total Sweat Production in Grams
130° Experiments		
A (age 30)	Control	1106
	SR	1444
	CN	1114
C (age 49)	Control	962
	SR	1280
	CN	1106
D (age 34)	Control	794
	SR	772
	CN	1066
160° Experiments		
B (age 30)	Control	993
	SR	988
	CN	1064
F (age 24)	Control	1063
	SR	1144
	CN	1004
G (age 47)	Control	658
	SR	
	CN	672
H (age 25)	Control	816
	SR	974
	CN	864
I (age 23)	Control	914
	SR	928
	CN	908

two is 88.1 or about 10 short of what was found empirically. It is stressed that in the case of subject D, calorie neutralization triggered the sweating mechanisms which somehow contributed to the huge amount of calories neutralized. We can reconcile these findings with those of subject C who also had increased sweat production, by noting that for subject C control levels of sweating were "normal" so that his average skin temperature was relatively low; this might imply that a lower fraction of the heat needed for vaporization of sweat came from his body. If we estimate that value to be 25 per cent one can account for about 13 Calories in addition to the 37, or a sum of 50. However, experimental results show that subject C neutralized only 19.4 Calories. What happened to the other 30?

Although it cannot be absolutely stated, the deficit in empirically-found vs. theroetically-expected neutralized calories will be present to some extent in practically all experiments. It is our current opinion that the increased load presented to the circulatory system in the form of an extra liter of fluid results in loss of efficiency in the contribution of this system to heat dissipation and thus accounts for the deficit. If this is so, one might expect older subjects to show a greater deficit than younger ones since their circulatory systems are less capable of the compensatory responses found in younger men. This concept is emphasized by data shown in Figure 2. The oldest subject in the 160 degree runs, subject G (age 47) neutralizes only 9.6 Calories of the theoretical 37 (q_e values after correction for body surface area), leaving a deficit of 27.4, whereas the youngest subject (I), age 23, neutralizes 45.0—8.0 more than theoretical.

The concept of more calories accumulating in older subjects as a result of increased circulatory burden (the liter of fluid) is also reflected in I_G (Accumlative Circulatory Strain Index) values. I_G is an estimate of strain on the circulatory system. A low I_G may mean one of two things: (a) that the circulatory system "has no need of being strained"; or (b) that it is not "capable of being strained." Case (b) applies to most older persons. Note that in subjects C (age 49) and G (age 47) all I_G values are low (under 1.00), that under increased stress to the circulatory system in the SR studies—they are still low, that they rarely exceed 1.00. This at first might be construed to indicate that these subjects are doing well; however upon further reflection and investigation this is seen to be erroneous.

It has frequently been noticed that during a typical 160 degree run, one of the compensatory circulatory responses is a decrease in peripheral resistance as evidenced by an increase in pulse pressure, the latter being generated chiefly by a drop in diastolic pressure. In young subjects diastolic pressure often drops to very low levels, whereas in older subjects there is very little alteration in diastolic pressure and if pulse pressure is increased at all it is usually accomplished at the expense of a rise in systolic pressure—an undesirable effect in heat. Therefore, from presumptive evidence it is felt that a low I_G in older subjects is not, as would initially seem, a good sign; it is just the opposite. It indicates that the subject's circulatory system is not capable of undergoing the wide range of compensatory responses in the augmentation of heat-dissipation.

The SR studies show that in the 130 degree experiments a liter of water at body temperature constituted an increased circulatory strain (higher I_G values) in subjects A and D. It is postulated that this would have been so for subject C, if his circulatory system would have responded to the stress. Even in the 160 degree runs, only where there was evidence of high I_G values were beneficial effect of sweat replacement observed. Subject H (age 25) showed a neutralization of 20.9 calories due to intake of a liter of 37° C. water. It can be seen (Table I) that under these conditions subject H sweated 160 grams more than in his control experiments. If only 20 per cent of the heat necessary for vaporization of this excess sweat came from his own body one could account for the 20.9 Calories. It can also be seen that subject H is capable of higher I_G levels (1.36), indicating that his circulatory system responds to the extra burden (a liter of water) for heat dissipation. In the case of subject I, although he did not have increased sweating, a liter of 37° C. water resulted in neutralization of 15.9 Calories. Although his I_G for SR was low (0.55) his I_G for the control observations was high (1.45) indicating that his circulatory system could respond to stress. The low I_G SR value of 0.55 can be interpreted to indicate that the liter of water did not constitute a burden to his circulatory system but a *relief* from a burden (heat exposure). In subject B where there is evidence of high I_G values, sweat replacement caused a neutralization of

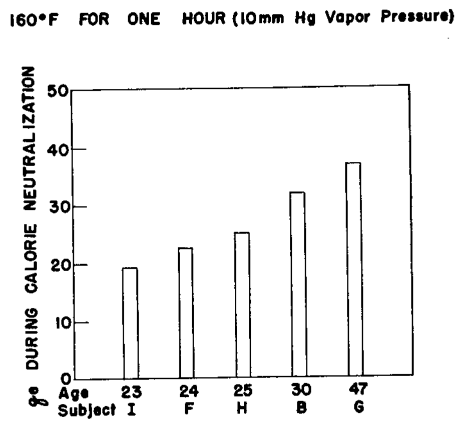

Fig. 3. The effect of age on effective body heat storage (q_e) during calorie neutralization, at 71.1°C. (160°F.) and 10 mm. Hg. vapor pressure for one hour.

24.5 Calories. However, in subjects F and G sweat replacement did not seem to help and in each of these cases the I_G fails to reach even 1.00. Subject F was twenty-four years old, thirty-five pounds overweight and this probably accounted for poor performance relative to his age. Overweight subjects frequently respond poorly.

As described above in the 130 degree experiments, both q_s and q_e CN values for all three subjects appeared to be essentially the same. This might possibly represent the lowest level at which a body could be expected to absorb heat under the given environmental conditions.

In the 160 degree runs it is interesting to note that under calorie neutralization the youngest subject absorbed only 18.9 effective Calories, whereas the oldest subject absorbed 36.5 (Fig. 3) with intermediate ages showing intermediate values which increase with increasing age. This is interpreted to indicate that with increasing age younger subjects obtain the greatest benefit from calorie neutralization and the oldest, the least. Hence it again appears that older subjects are the least satisfactory and this is confirmed in other studies.[7]

Finally, it can be seen that under calorie neutralization both I_s and I_G decrease. The decrease in the Modified Craig (I_s) Index means that the subject has incurred less strain. In the Accumulative Circulatory Strain (I_G) Index it means that the administration of ice water aids the circulatory system in dissipating heat so that less stress is imposed than without ice water administration.

SUMMARY

The benefit of calorie neutralization is that the body must expend 37 Calories on a liter of ice water but another benefit is that it provides an additional liter of fluid that can be eventually used for sweating and although this is not necessarily reflected in an increased sweat rate, it is reflected in a *prolongation* of sweating time.

The 130 degree experiments were not rate limiting so far as exposure time is concerned. Even without the administration of ice water, all subjects could easily have tolerated periods longer than two hours. However, with the administration of a liter of ice water, it is estimated that subjects would be able to remain at the same degree of relative comfort, at least 75 and probably 100 per cent longer.

Exposure time to 160 degrees is limited especially for older subjects. In the case of subject I, a typical young subject, his q_e for calorie neutralization was 24.4 Cal/m²/hr, whereas his control was 47.4. This means that he would have 23 effective Calories more to absorb which would have required at least another half-hour. Moreover if the liter of ice water were administered over a period of two hours (instead of one hour) it is estimated that the subject could have remained an extra hour. Thus at 160 degrees it is our opinion that a liter of ice water can extend the useful time of exposure at least 50 per cent (and possibly 100 per cent) for young subjects whose circulatory systems show adequate compensatory responses.

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Changing Concepts in Physical Standards for Flying

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PHYSICAL standards for flying in the United States Air Force have not changed significantly in the past two decades. What have been changing, however, are the interpretations of medical findings and their application in the flying environment as individuals are required to perform more and more complex functions in more and more hostile surroundings. There have been many refinements in physical examination techniques which are reflected in more extensive and thorough testing procedures. The statement of the responsibility of the Air Medical Service in the pilot selection program of World War I is just as appropriate today as it was in 1917: "No aviator shall fail in his mission because of any discoverable physical defect."[2]

Major General Oliver K. Niess, Air Force Surgeon General, recently reminded us that aerospace medicine is firmly rooted in World War I. It became apparent early in the first World War that physical defects of the pilots rather than structural defects of the aircraft were responsible for the majority of accidents, injuries and fatalities which occurred in connection with aerial combat.[16] Flying safety requires that substandard aircrew personnel be kept out of the air. The aircrew population should not be diluted with substandard individuals. If this occurs, the aircraft accident rate will rise. It is the responsibility of the flight surgeon to prevent this dilution with medically substandard individuals.[18,24]

In 1907, thorough physical examination procedures were undertaken to determine applicants' fitness for aviation duty. Passing the standard physical examination required of all recruits was the basic requirement, but in addition, applicants for flying were more carefully tested for abnormalities of the eyes, ears, and the cardiovascular system. Emphasis was placed on tests of equilibrium to determine vestibular function. In May 1917, a separate physical examination for flying was devised. Detailed instructions were given medical officers regarding examination of the eyes and ears, and evaluation of the temperamental qualifications. For the first time, medical personnel were especially trained to perform physical examinations for flying.[5] There have been many improvements and refinements in examination techniques since those early days. For

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example, in the evaluation of physical fitness in the Mercury project, the Man-in-Space program, general physical requirements were established by the NASA Life Sciences Committee. Since the individuals to be examined were active test pilots, it was not anticipated that any would be disqualified as physically unfit. Degrees of physical soundness of the candidates were obtained by thorough and exhaustive testing and examination. The evaluation and grading were dependent upon a comparison of each candidate to his fellows. To establish a comparative yardstick, the medical selection program consisted of a complete aviation and medical history, psychophysiological examination, stress-testing procedures, and clinical appraisal of suitability. The seven men ultimately selected to participate in the program were chosen as a result of physical, psychological and stress tolerance capabilities and, in addition, because of the technical experience possessed by each.[17,19]

It has been repeatedly stated by many intimately connected with aerospace planning for the future, that manned aircraft will be with us for a long time to come. Because man is accustomed to living in the earth's atmosphere, it is proper to speak of the operational realm beyond the earth as "aerospace." Since there is no arbitrary division where atmosphere ends and space begins, aerospace describes the operationally indivisible medium of the total expanse beyond the earth's surface.[1] General Thomas D. White, Chief of Staff of the United States Air Force, recently stated that downgrading of the importance of manned aircraft is dangerous, and that the requirement for manned aircraft will continue for as far into the future as he can see. He stated that there are a number of advantages inherent in manned aircraft operations which missiles do not yet and may never be able to provide. Aircraft can be launched at any time an attack appears imminent and can be recalled if the attack fails to develop. Aircraft can be diverted from one target to another, can take many kinds of evasive and defensive actions, can attack several different targets, or perform combined or varied tasks on the same flight. Aircraft can be used over and over again. It is apparent that these advantages result from the presence of human judgment and decision making capability in the cockpit and at the controls, in the vehicle itself.[26]

Turning from military aerospace operations one has but to look at the great developments in commercial aviation to appreciate the fact that man will be flying and controlling aerospacecraft for a long time to come. Our great commercial transport fleets are rapidly being converted to turboprop and turbo-jet equipment. Even higher-performance, longer-haul, greater-load capacity aircraft are on the planning boards at the present time for development within the immediate future. A Mach 3 airliner with a 90,000-feet cruising altitude is being designed now.

Refinements of physical examination techniques and procedures will continue and closer medical surveillance of flight crews, such as recommended by the Federal Aviation Agency within the past year, will become even more apparent. Reference is made to Civil Air Regulations Amendment No. 29-2, effective October 15, 1959, and Civil Air Regulation Draft Releases No. 59-5, June 27, 1959, and No. 59-2, April 14, 1959.[6,7,8] F.A.A. regulations now specifically disqualify civilian applicants for airmen certificates for any class who are suffering from diabetes mellitus requiring hypoglycemic medication, those who present substantiated evidence of coronary heart disease, a history of psychosis or severe psychoneurosis, severe personality defects, epilepsy, chronic alcoholism, or drug addiction. Draft No. 59-5 proposes that no individual who has reached age 55 shall be utilized in command of a flight crew of three or more pilots on turbojet aircraft engaged in air-carrier operations unless he has held such a rating prior to his fifty-fifth birthday. In addition, no individual who has reached his sixtieth birthday may serve as a pilot on any aircraft engaged in air-carrier operation.

No individual should be considered medically qualified to perform flying duties if he possesses any physical, mental or emotional defect or disability which could or would adversely affect the safety of flight or unduly jeopardize his welfare or that of his crew and passengers. Common sense dictates that in any case where there is a question of physical qualification which might jeopardize flying safety, the individual should be grounded.[21]

Physical standards for flying in the United States Air Force are described in detail in Air Force Manual 160-1.[15] This manual was first published in 1951 and has been rewritten and revised several times since. A complete revision is presently in progress. Excellent suggestions pertaining to changes in the manual, and physical standards for flying, have been received from many sources. Careful evaluation of these recommendations has shown that major changes in physical requirements are not required and it is anticipated that the standards reflected in the revision will not differ greatly from the present ones. Some sections of the manual may reflect requirements for more detailed information and testing.

Physical standards for flying are designed to select those applicants for flying training who possess the highest probability of becoming safe, proficient and successful crew members. Physical standards are also designed to identify those who, due to physical, mental or emotional defects, might not be expected to serve in a flying capacity long enough to repay the training investment. They should also screen out individuals who possess or who are likely to develop disabilities which might affect flying safety, reduce flying proficiency or result in early retirement from flying duties.[4]

Interpretation of physical standards, as they relate to flying is dependent to a certain extent upon the law of supply and demand. In view of the complexity of present-day and projected aerospacecraft, there must be no compromise in quality in the initial selection process. The standards serve as a yardstick and when waiver is considered, the risk must be weighed against the training, experience, and value of the individual. In the final analysis, physical standards must be high enough to eliminate those with a relatively low order of medical fitness, yet low enough to ensure the acceptance of sufficient numbers to supply satisfactorily trained individuals to accomplish the mission, whether it be military or civilian.[2,18]

Too strict application of the results of laboratory tests is dangerous. In 1943, Clamann and Luft working with pressure breathing found that the T-waves in electrocardiographic tracings were flattened or inverted after subjects breathed oxygen at pressures from 10 to 30 mm. Hg for as little as twelve minutes. They interpreted these changes as representing myocardial strain. As a result of their work, German aeromedical authorities decided not to risk additional danger to the heart and circulation of Luftwaffe pilots for the sake of gaining an additional 3,000 to 6,500 feet in altitude.[9] It was not until later that it was determined that these were non-specific T-wave changes and were not pathognomonic of myocardial strain, hypoxia, or ischemia. One of the observations of Lamb and his co-workers is that labile T-waves and non-specific T-wave changes are probably the most common electrocardiographic findings in the Air Force flying population. They have demonstrated that T-wave changes may be caused by anxiety and other emotions, recent ingestion of food, postural changes, respiratory maneuvers, and a host of other factors, and that T-wave lability under these conditions is not indicative of cardiovascular disease.[10,11,12]

From the foregoing it appears that the misinterpretation of the results of laboratory tests and its application to the flying environment resulted in the discarding of development of more advanced equipment which could conceivably have changed the complexion of the air battle over Europe. Correct interpretation of laboratory tests and examining procedures is exceedingly important in the selection of individuals for flying and in the medical supervision of fully-trained, experienced personnel.

There has been widespread misunderstanding of the requirement that individuals, selected for flying training, must have a "normal" electrocardiogram. An Air Force regulation was published in 1957 which required the recording of a twelve lead electrocardiogram on all rated officers on flying status.[25] Tracings also were to be made on all selectees for flying training and applicants for the Air Force Academy. Previously, there had been only a requirement that individuals over age forty have electrocardiograms made. As a result of this baseline electrocardiographic survey, more than 67,000 tracings have been studied and are on file at the Aerospace Medical Center, Brooks Air Force Base, Texas. Much information has been obtained from these tracings and the findings are comparable to those published by Manning and FitzGibbon in 1956 in a survey of aircrew applicants for the Royal Canadian Air Force.[14] In the U. S. Air Force, the entire number of electrocardiographic abnormalities was found to be less than 4 per cent, and only a small proportion of these was of sufficient significance to be considered as evidence of cardiovascular problems which compromise flying safety.[11] It became apparent that several terms used in electrocardiographic diagnosis which suggest significant underlying cardiac disease should be changed.[20] Although the pattern of numbers of tracings appears unusual or abnormal, extensive study and exhaustive clinical evaluation of many representative cases have shown that a considerable proportion of these are variations of normal. For military record-keeping purposes, however, since the tracings represent a deviation from the accepted normal, notwithstanding the absence of pathology, it became apparent that a notation concerning the abnormal tracing should be made. If underlying cardiac disease is absent, cardiovascular hemodynamics normal, and the abnormality does not constitute a potential hazard to the safety of flight, a waiver is granted by the surgeon general, USAF. After a thorough clinical evaluation by a competent cardiologist and in the absence of any evidence of underlying heart disease or abnormality of cardiovascular function, atrial, nodal and ventricular prematurities, and incomplete right bundle branch block (delayed activation over the right ventricle) may be accepted as normal variants.[11]

There may have been a few individuals medically disqualified for flying in the past due to cardiac findings which were previously considered to represent pathology or to present a hazard in the flying environment, who now, based upon additional knowledge, could be considered qualified for flying duty. This situation parallels somewhat that of the T-wave change finding of the Luftwaffe. In both situations, the error was on the side of flying safety.

The application of more thorough testing procedures of the cardiovascular system and more accurate interpretation of the findings have supplied better criteria for the selection of individuals to be trained and for continuance in aerospace operations of those already trained and experienced. The example of the electrocardiographic mass survey and ultimate separation of variations of normal from the abnormal might be applied to other organ systems and functions of the body. Baseline electroencephalographic tracings should be considered in order to better determine the "normal" in a large selected population such as in the flyer group. Such a project could be of as great value to the neurologist and neurophysiologist as the electrocardiographic study has been to the internist and cardiologist. In addition, for "super-selection" the effects of stress and adverse environment could be added to the generally employed procedures. This has been done in the Mercury Project and will be of great value in other future procedures.[3,17]

Higher-performance aerospace equipment and ventures farther from the earth's surface may bring about other refinements in testing and examination procedures and some changes in physical standards. It has been recommended that distant visual acuity of 20/15 be required for entrance into flying training in the USAF. An additional suggestion has been to require at least 0.5 diopter of hyperopia in all meridians for initial selection. Speed and performance characteristics of jet and rocket aerospacecraft demand superior visual acuity, and until television or other cockpit presentation devices or systems are available, acute uncorrected vision will continue to be an urgent requirement.[2] The use of contact lenses has not been found satisfactory in operational flying, and spectacles are frequently a hindrance when worn with the partial- or full-pressure suit. It is possible that color vision requirements could be relaxed to the extent that pseudo-isochromatic plates would be used as a qualitative screening test and qualification made on the quantitative S.A.M. color threshold tester with a predetermined cut-off score based upon operational requirements.

It has been proposed that the hemoglobin type of negro applicants be determined by paper electrophoresis, a relatively simple procedure. Individuals with AS and SS hemoglobins should be tested in the altitude chamber and those with SC hemogloblin considered for rejection from all flying training programs due to the danger of sickling and hemolysis which can occur under relatively minor hypoxic conditions.[22]

It has been widely postulated that there is a connection between obesity and atherosclerosis, and there appears to be a direct relationship between obesity and dysbarism. The present weight tables used by the Air Force have been under scrutiny for a long time. It has been recommended by several authorities that the present standard weight and minimum weight for height and age be retained, and that the maximum allowable weight be reduced to the standard plus 15 per cent. This appears to be a more reasonable figure, but still is far from the ideal, that of lean body mass plus 10 per cent.

A history of syncope[2] is considered disqualifying for flying training. Loss of consciousness not adequately explained and without objective medical evidence indicating cause, is reason for disqualification for flying duty.[15]

A survey was recently carried out in which an Air Force population completed questionnaires regarding syncope or loss of consciousness. Ninety-eight per cent of 1,056 individuals queried, replied. All replies were anonymous. The ages ranged from twenty-four years through forty-five years of age. Four hundred twenty three (40.9 per cent) listed one or more previous episodes of loss of consciousness, and of these, 139 experienced two or more episodes. Six hundred ten (59.1 per cent) individuals denied ever experiencing loss of consciousness.[13] This study, which goes into great detail regarding the causes for loss of consciousness, age, number of incidents, association with environmental factors, trauma, et cetera, tends to bear out a general impression that there is more syncope in flying personnel than is reported, and that in the selection process applicants tend to neglect to relate to the examiner such incidents, possibly with the knowledge that a history of these occurrences is disqualifying. Syncope (interference with the normal train of consciousness requires considerable study in order to better define adequacy of cause or explanation for such episodes.

For the purposes of flying status in the Air Force, a waiver is not intended to be used as a backdoor for the individual who does not qualify or meet the physical requirements. It is a means of permitting acceptance or retention of those who have demonstrated that even with their disqualifying defects they can still be expected to perform effectively and on a par with others who meet the minimum standard or requirement. Waivers are not granted for entrance into flying training. When a waiver is granted for continuation in flying training or for retention on flying status, the defect must be non-symptomatic, should be static, and should not include actively progressive or disabling degenerative disease processes. Any condition or defect which will interfere with the performance of unlimited flying duty is not normally waived. The individual is not given a waiver; the Air Force waives its requirement that the individual meet a certain minimum standard. Thus personnel are in reality not "qualified with waiver" but rather are "acceptable with waiver," since in actuality they are not qualified. Waivers for individuals already trained allow for certain variations in physical standards and for differences in the nature and severity of the defects.[23]

SUMMARY

It has been noted that physical standards for flying have not changed significantly over the years. There have been refinements in examination techniques and improvements in evaluation of essential organ systems. These advances should ultimately be reflected in more accurate measurement of physical adaptability and capability for aerospace flight. Physical standards, undergoing constant study and evaluation, are being interpreted in somewhat different terms of reference. Recommendations for minor changes in visual requirements and weight standards have been mentioned. Certain electrocardiographic findings previously thought to represent pathology or abnormal conduction within the heart have been shown by aviation cardiologists to be normal variations and of no clinical significance. Reference has been made to the use of paper electrophoresis in identifying individuals with abnormal hemoglobins and the recommendation made that it would be wise to restrict certain of these from aerospace operations.

Man is unchanged, but his operational environment has become more and more hostile and unforgiving, and his duties more taxing and complex. It is anticipated that within the foreseeable future further application of the results of laboratory tests and mass surveys will assist the flight surgeon in even better selection of candidates for the job at hand, be it flight five miles above the earth's surface, 500, 5,000, or beyond.

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REPORT

from the President

Aerospace Medical Association

The plans for our 1961 convention, April 24 through April 27, 1961, which will be held at the Palmer House in Chicago, Illinois, are progressing very satisfactorily. The physical layout of the Palmer House is superb in that our three main meeting halls will be on the convention floor and easily accessible from the registration area. The fine accommodations at the Palmer House will permit us to hold ancillary functions, such as luncheons, committee meetings, and Fellows dinner, within the confines of the hotel.

The scientific program is progressing well. Dr. John Marbarger has asked me to point out again to our members that December 1, 1960 is the deadline for the presentation of abstracts. In order for the Scientific Committee to organize the program properly, those of you wishing to submit a paper for presentation at the convention are urged to respect the deadline.

The Wives Wing will again arrange an interesting program. A Hospitality Room for registration and "kaffee klatsching" will be provided.

This year, Dr. James Keehan, Chairman of the Registration Committee, is planning for pre-registration. All members will receive a pre-registration blank, upon which they can indicate the functions they wish to attend. The Registration Committee will then prepare in advance the badges and envelope of tickets individually requested. A pre-registration desk will be set up and those thus registered will avoid the morning rush and confusion which has taken place in the past in the registration area. While such an ambitious pre-registration program has never been undertaken, it is contemplated that it will be well received by our members.

The technical exhibit booth sales are progressing slowly but surely. Mr. Michael I. O'Connor, Williams & Wilkins Company, 428 East Preston Street, Baltimore 2, Maryland, would appreciate having you refer to him the name of any company which has a product which you believe would be of general or special interest to our membership.

At the recent meeting of the Executive Committee, which is also the Convention Site Committee, it was recommended that the 1963 convention be held in California, and the 1964 convention be held in Miami, Florida. These selections complement our 1962 convention in Atlantic City, thereby giving us a good geographical spread for future conventions.

G. J. Kidera, M.D.
President

Aerospace Medical News

Civil Aviation Medical Association Board Meets

The Civil Aviation Medical Association Board of Trustees held its semi-annual meeting at the Drake Hotel, Chicago, Illinois, on October 8, 1960. The meeting was chaired by President Delbert F. Rey; other Board Members present were Drs. Neal E. Baxter, Howard A. Dishongh, Herbert F. Fenwick, J. Harold Brown, Aris Carpousis, Dominic T. Chechile, Thomas A. Coates, Colvern D. Henry, Lauren G. Welch, W. J. Kennard, Louis F. Raymond, George B. McNeely, and Joel Fisher, Executive Secretary.

Guests from the Bureau of Aviation Medicine, Federal Aviation Agency, gave talks and led a discussion period at the luncheon. FAA guests included Drs. Hugh G. Whitehead, Arthur E. Wentz, Frank A. Raymond, and Oscar H. Comess. Dr. Wentz represented Dr. James Goddard, the Civil Air Surgeon, who had planned to attend.

Unanimous Resolution

One of the major actions taken by the Board of Trustees was unanimous adoption of a resolution commending the Federal Aviation Agency for its program of civil aviation medicine. The complete resolution follows:

WHEREAS, an effective program of civil aviation medicine is one of the important methods of increasing safety in air commerce; and

WHEREAS, the Federal Aviation Agency has since its inception been developing and carrying out a professionally sound civil aviation medical program; and

WHEREAS, certain special interest groups have been seeking to curtail and frustrate the civil aviation medical program of the Federal Aviation Agency and have been seeking to introduce into the present political campaign the issue of administration by the Federal Aviation Agency of its safety program; and

WHEREAS, such efforts are deplored by this Association as are any efforts to make political footballs out of aviation medical programs which are necessary in the public interest; and

WHEREAS, the public interest requires that the civil aviation medical program of the Federal Aviation Agency continue to be developed and administered without reference to political considerations or the views of any special interest group;

THEREFORE BE IT UNANIMOUSLY RESOLVED, by the Board of Trustees of the Civil Aviation Medical Association, a constituent organization of the Aerospace Medical Association, in meeting duly assembled at the Drake Hotel in Chicago, this 8th day of October 1960, that:

1. The Federal Aviation Agency be, and hereby is, commended for its program of civil aviation medicine; and
2. The Federal Aviation Agency is encouraged to continue to administer its civil aviation medical program in the pubilc interest in order to increase safety in air commerce; and
3. This Association will continue to cooperate with and assist the Federal Aviation Agency in all ways possible in carrying out a well-balanced and mature civil aviation medical program; and

4. The Executive Secretary of this Association is instructed to forward a copy of this Resolution to the Presidential candidates of both major political parties; and

5. The Executive Secretary is instructed to forward a copy of this Resolution to the Administrator of the Federal Aviation Agency.

FAA Creates Medical Advisory Panel

The Federal Aviation Agency is creating a Medical Advisory Panel to provide for an impartial review of petitions from airmen for exemptions from medical standards of the Agency. The Panel, which will be named in a few weeks, will be composed of medical specialists and will be asked to provide recommendations on all petitions for exemptions to Part 29 of the Civil Air Regulations. Specifically, the panel of medical specialists will consider each petition and provide the FAA Administrator with recommendations as to whether "the specific nature of the medical defect of the applicant . . . is such that he may be exempted from such standards without endangering the safety of the public during the period of validity of such medical certificate." Final action on the petition will be taken by the FAA Administrator on the advice of the Medical Advisory Panel.

Authority Delegated

This new procedure will become effective in about sixty days after the naming of the advisory panel and the establishment of the necessary mechanics for its operation.

In a related action, FAA took steps to expedite decisions on medical certificates by delegating additional authority to aviation medical examiners. FAA has designated approximately 3500 physicians in all parts of the country to serve as aviation medical examiners. These private physicians have the responsibility of examining applicants for all classes of ratings and are required to maintain detailed knowledge of published medical standards and directives. Under the new delegation of authority, now effective, the medical examiner is permitted both to issue and deny issuance of medical certificates to applicants he examines.

Lt. Col. Beyer Heads Flight Medicine Branch


Dr. Beyer

Lt. Col. David H. Beyer, USAF, has been named Chief of the Flight Medicine Branch at the School of Aviation Medicine, Brooks Air Force Base, Texas. He succeeds Major Robert R. Burwell, who has left for an assignment in Germany.

Colonel Beyer recently returned from Hickam Air Force Base, Hawaii, where he served as Chief of the Aviation Medicine Division at headquarters Pacific Air Forces.

A senior flight surgeon, Colonel Beyer received his M.D. degree from the University of Maryland in 1948 and his Master of Public Health degree from Johns Hopkins University in 1955. He is a diplomate of the American Board of Preventive Medicine in Aviation Medicine, a fellow of the American College of Preventive Medicine, and has been a member of the Aerospace Medical Association since 1952.

New Assignment for Captain Phoebus


Captain Phoebus

Captain Clifford P. Phoebus, USN, formerly the Director of the Astronautical Division of the Bureau of Medicine and Surgery of the Navy Department, has received a new assignment. He is now the Commanding Officer of the U. S. Naval School of Aviation Medicine, U. S. Naval Aviation Medical Center, Pensacola, Florida, having relieved Rear Admiral Langdon Newman, USN, who was ordered to duty as the Inspector General, Medical, in the Bureau of Medicine and Surgery.

Captain Phoebus is a veteran flight surgeon. He received his initial training at the

Army School of Aviation Medicine at Randolph Field, Texas, in 1938, and since that time has been continually associated with aviation medical activities of the Navy. He reported for his new assignment in Pensacola on 18 October, 1960.

New Assignment for Colonel Stapp

COLONEL STAPP

Colonel John Paul Stapp, USAF, who until recently was chief of the Aerospace Medical Division at the Wright Air Development Division, Wright-Patterson Air Force Base, Dayton, Ohio, has become Special Assistant for Aerospace Medicine in the USAF Aerospace Medical Center's Advanced Studies Group.

Colonel Stapp, called the "fastest man on the ground," is well remembered for his rocket sled tests at speeds up to 632 miles per hour. On December 10, 1954, he rode a rocket-propelled sled at this high speed in one of a series of human sled runs to determine the effects on pilots bailing out at very high altitudes and at supersonic speeds. During this test, Colonel Stapp's sled was braked to a halt in 1.4 seconds, imposing an average force of 25 times his own weight on his body. Highest force during the sudden halt was 40 times his own weight.

Colonel Stapp received his M.D. degree at the University of Minnesota in 1944. He is a diplomate of the American Board of Preventive Medicine in Aviation Medicine, and has been a member of Aerospace Medical Association since 1945.

General Officers to New Commands

Several general officers of the United States Air Force have new assignments involving the Senior Medical Officer of a number of major Commands.

Brigadier General Benjamin A. Strickland, Jr., USAF, MC, formerly Surgeon of Air Defense Command, in October assumed his new duty as Deputy Assistant for Bioastronautics at Headquarters, Air Research and Development Command. In his new position, General Strickland is Deputy to Brigadier General Don Flickinger, USAF, MC.

Another recent arrival at Air Research and Development Command was Colonel Julian A. Jarman, USAF, MC, who has assumed the duties of Command Surgeon, Air Research and Development Command, with Colonel Philip G. Keil, USAF, MC, as Deputy Surgeon, in addition to his previous assignment as Chief of Professional Services.

Brigadier General James G. Moore, USAF, MC, has replaced General Strickland as Surgeon, Air Defense Command, in Colorado Springs, Colorado. General Moore was relieved by Brigadier General James W. Humphreys, Jr., USAF, MC, formerly Commander of the USAF Hospital, Wright-Patterson AFB, Ohio, now assigned Commander USAF Hospital Lackland, Lackland AFB, Texas.

General orders published in October direct that Brigadier General Theodore C. Bedwell, Jr., USAF, MC, is relieved from duty as Surgeon of Strategic Air Command and is assigned for duty as Commander, USAF Aerospace Medical Center (ATC) at Brooks AFB, Texas, reporting February 1, 1961.

Dr. Reighard at Harvard

Dr. Homer L. Reighard, Chief of the Medical Standards Division of the Federal Aviation Agency's Bureau of Aviation Medicine, is on temporary leave from the Agency to attend Harvard University to study for a Master's Degree in Public Health Administration.

Dr. Reighard is attending Harvard for one year under the Government Employees Training Act, which provides specialized training for employees who have or who will be given particular responsibilities for which specialized training is required.

Dr. Wayne R. Otto, Chief of the Rules and Procedures Branch, has been named by Civil Air Surgeon, Dr. James L. Goddard, to serve as acting chief of the Medical Standards Division during the absence of Dr. Reighard.

News of Members

Captain **P. S. Kwiatkowski,** USN, formerly Medical Officer in the *USS Antietam,* is now the Medical Officer at the U. S. Naval Air Station, Glynco, Brunswick, Georgia. . . . Lieutenant Colonel **Richard M. Fenno,** USAF, formerly assigned to Headquarters 12th Air Force, Waco, Texas, has transferred to the 839th Tactical Hospital, Sewart AFB, Tennessee. . . . Captain **Carl W. Holl, Jr.,** USAF, is assigned to the 10th Tactical Hospital, overseas. . . . Lt. Commander **Clarence E. Gossett,** USN, is under residency training in Aviation Medicine at the Naval School of Aviation Medicine, Pensacola. . . . Major **W. R. Hawkins,** USAF, is now assigned to the Aerospace Medical Division, Directorate of Professional Services, Office of the Surgeon General, USAF, Washington, D. C. . . . **Edwin P. Hiatt,** Ph.D., M.D., has moved from New Carlisle, Ohio, to Wilmington, Ohio. . . . **John P. Kemph,** M.D., has transferred his practice from Elida, Ohio, to Ann Arbor, Michigan. . . . **Kenneth L. Stratton,** M.D., has left American Airlines and is now a Medical Director with the Bell Telephone Company in New York. While Dr. Stratton has relinquished some of his offices in aerospace medicine and the airlines activities, in view of his background and experience in aviation medicine, we will continue to call upon him for his advice and assistance on Association matters. . . . Major **W. H. Shea,** USAF, formerly at Wright-Patterson AFB, Ohio, is now assigned to the 2716th Dispensary, overseas. . . . Captain **J. R. Snoga,** USAF, is under residency training in Pathology at Letterman General Hospital, San Francisco. . . . Captain **Howard R. Unger,** USAF, has transferred from Wright-Patterson AFB, to 810th Medical Group, Fairchild AFB, Washington. . . . Captain **Paul Vaughan,** USN (Ret.), has moved from Memphis, Tennessee, to Arvada, Colorado. . . . Captain **Philip W. Andrews,** USAF, is assigned to the School of Public Health at the University of California, Berkeley, California. . . . Captain **Victor G. Benson,** USN, is now under residency training in Aviation Medicine at the Naval Aviation Medical Acceleration Laboratory at Johnsville, Pennsylvania. . . . Captain **Kenneth H. Cooper,** USAF, formerly of the U. S. Army at Fort Sill, Oklahoma, is attending the School of Aviation Medicine, Brooks AFB, Texas. . . . **Paul E. Dittman** has moved from Seattle, Washington, to Cambridge, Massachusetts. . . . Commander **W. L. Erdbrink,** USN, of Oakland, California, is on the staff of the School of Aviation Medicine, U. S. Naval Aviation Medical Center, Pensacola, Florida. . . . Captain **Richard N. Betz,** USAF, is newly assigned to the 327th Hospital, overseas. . . . Captain **Arnold R. DeMarco,** USA, is now assigned to the 618th Medical Company, overseas. . . . Dr. **William J. Henry** has moved from Oak Harbor, Washington, to Pittsburgh, Pennsylvania. . . . Lt. Colonel **Nicholas H. Nauert, Jr.,** USAF, has been assigned to the 7112th Central Medical Group overseas. . . . Captain **Thomas S. Culley,** USAF, is now assigned to the Orthopedic Division of the USAF Hospital at Keesler AFB, Mississippi, and is working closely with the Aviation Medicine Section there in evaluating the fitness of rated personnel in regard to musculo skeletal problems. . . . Captain **Mary F. Foley** (NC), formerly at the USAF Hospital, Scott AFB, Illinois, has been released from active duty in the Air Force Nurse Corps, and is presently a graduate student in the Department of Physiology, University of Illinois. . . . Captain **J. F. Wittmer,** USAF, is assigned to the Harvard School of Public Health, for study in Aviation Medicine. . . . Lt. Colonel **J. G. Borman,** USAF, formerly assigned to Scott AFB, Illinois, is now with the 47th Tactical Hospital, overseas. . . . Captain **R. L. Masters,** USAF, is assigned to the Harvard School of Public Health for study in Aviation Medicine. . . . Colonel **Robert H. Holmes,** MC, USA, formerly with the Armed Forces Institute of Pathology, is now assigned to the

Office of the Surgeon, Defense Atomic Support Agency, Washington, D. C. . . . Spacelabs, Inc., pioneering firm in Space Medicine, recently announced the appointment of **George H. Sullivan,** M.D., BSEE, as Medical Director. Dr. Sullivan will be responsible for advanced bio-medical research and instrumentation programs. At present he is engaged in development of a much improved blood pressure monitoring instrument. . . . **Edwin P. Hiatt,** Ph.D., M.D., is leaving his post as chief of the Biophysics Branch, Aerospace Medical Labs, Wright-Patterson AFB, Ohio, to take a new post as Professor of Physiology, School of Medicine, Ohio State University, Columbus, Ohio. . . . **Frederick W. Lovell,** M.D., formerly a Major, USAF, MC, and until recently chief of the Aviation Pathology Department of the Armed Forces Institute of Pathology, has returned to Seattle, Washington, where he formerly practised. . . . **Edmund J. Manogue,** M.D., has moved from Silver City, New Mexico, to Masilla Park, New Mexico. . . . Major **Robert R. Burwell,** USAF, formerly at Brooks AFB, Texas, is now assigned to the 7310th Dispensary, overseas. . . . **James B. Degner,** M.D., has moved from Savannah, Georgia, to Wichita, Kansas. . . . **Frank DiTraglia,** M.D., has moved from Alexandria, Virginia, to Farhills, New Jersey. . . . **George A. Clark,** M.D., has moved from Birmingham, Michigan, to Indianapolis, Indiana. . . . Col. **Lawrence R. Sutherland,** USAF, formerly Commander of the 819th Medical Group at Dyess AFB, Texas, is now Commander of the 7520th USAF Hospital, overseas. . . . Lt. Colonel **Robert M. Tirman,** USAF, of Travis AFB, California, is now assigned to the 7230th Dispensary overseas. . . . Major **Frederick W. Wiese,** USAF, has transferred from Lackland Air Force Base, Texas, to 5040th USAF Hospital, overseas. . . . Major **Myron J. Woltjen,** USAF, is attending the Advanced Course at the School of Aviation Medicine, Brooks AFB, Texas. . . . Lt. Colonel **Marshall Y. Kremers,** USAF, has returned from overseas and is now Commander of the 4th Tactical Hospital, Seymour-Johnson AFB, North Carolina. . . . Captain **Howard A. Minners,** USAF, is attending the Advanced Course at the School of Aviation Medicine, Brooks AFB, Texas. . . . Lt. Colonel **George C. Jernigan,** USAF, has transferred from MacDill AFB, Florida, to 864th Medical Group, Laughlin AFB, Del Rio, Texas, as Commander. . . . Major **H. E. Wuesthoff, USAF,** who has returned from overseas, and is now Chief of Psychiatry at the USAF Hospital, Travis AFB, California, has received the Air Force Commendation Medal from Hospital Commander, Col. John Ficicchy, Jr., for outstanding service while overseas. . . . Major **Clinton L. Holt,** USAF, has also returned from overseas, and is attending the School of Public Health, Harvard Medical School, Boston, Massachusetts. . . . Captain **V. H. Heinz,** USN, formerly the Medical Officer in the USS Oriskany, is now the Medical Officer of the Naval Air Station, Seattle, Washington. . . . Lt. Commander **Roger G. Ireland,** USN, formerly at Johns Hopkins University undergoing instruction in Public Health leading toward certification in Aviation Medicine, is now at the Naval School of Aviation Medicine, Pensacola, for duty under instruction in residency training in Aviation Medicine. . . . **Robert C. Armstrong,** M.D., has moved from Lemon Grove, California, to La Mesa, California. . . . Group Captain **Hugh J. Bright**, M.D., D.P.H., has moved from Willowdale, Ontario, Canada, to Elmvale Acres, Ottawa, Ontario, Canada. . . . Mr. **Walter E. Tolles** has moved from Mineola, New York, to Deer Park, New York. . . . **Walter Kuehnegger,** Ing. Dipl., has moved from Littleton, Colorado, to Palo Alto, California . . . . Cdr. **Robert E. Mitchell**, USN, is on the Staff of the Naval School of Aviation Medicine, Naval Aviation Medical Center, Pensacola, Florida. . . . Lieutenant **August H. Wells**, USN, is with Carrier Air Group 21. . . . During a recent trip to the Space Task Group, NASA, Langley Air Force Base, Captain **Frank B. Voris,** USN, and Captain **Anthony P. Rush,** USN, viewed the operation of the static flight procedural trainer to be used by the Astronauts assigned to Project Mercury. This trainer is a typical capsule with instrument display panel, life support equipment, and controls. . . . Captain **Edward A. Anderson,** USN, senior medical officer at the U. S. Naval Air Station, Quonset Point, Rhode Island, received the highest decoration of the U. S. Volunteer Life Saving Corps at a special meeting in Wickford, Rhode Island, on August 10, 1960. The Volunteer Life Saving Corps Gold Medal of Honor was presented to Captain Anderson by the Rhode Island group for his efforts to help stem the spread of a dangerous polio epidemic in the state. . . . Lieutenant **William P. Mulligan,** USN, formerly with Fighter Squadron 101, has been transferred to the Naval Hospital at Oakland, California. . . . Lieutenant **Lowell T. York,** formerly assigned to the Naval Air Station at New Orleans is now assigned to OPERATION DEEP FREEZE, Antarctic Support Activities. . . . Capt. **Earland E. Hedblom,** USN, has received the Navy Letter of Commendation with Commendation Ribbon and Metal Pendant at the National Naval Medical Center, Bethesda, Maryland, in recognition of "outstanding performance of duty from 2 May, 1955, to 14 April, 1959, while serving as Staff Medical Officer, United States Naval Support Force Antarctica."

COMING EVENTS

November 30, 1960, 8:00 p.m. "Furthering Basic Biological Knowledge Through Space Research," Dr. J. L. Biedler, at the New York Academy of Sciences, under the auspices of the American Astronautical Society.

January 16-20, 1961. Lectures in Aerospace Medicine, to be conducted at the School of Aviation Medicine, Brooks Air Force Base, Texas, sponsored by the USAF School of Aviation Medicine, Aerospace Medical Center (ATC).

New Members

Victor Alzamora-Castro, M.D., San Isidro, Lima, Peru
Paul E. Anzinger, M.D., San Francisco, California
Raymond F. Austin, Jr., Lieutenant, USNR
Baird M. Bardarson, M.D., Renton, Wash.
Donald Lee Becker, Captain, USAF
Ernest M. Bilmes, Captain, USAF
Hugh C. Blodgett, Ph.D. Austin, Texas
Joseph D. Boggs, M.D., Chicago, Illinois
Richard J. Byrne, Captain, USAF
Robert P. Cavallino, Captain, USAF
Phillip H. Darling, Lieutenant, USAF
Philip J. Del Vecchio, Jr., Captain, USAF
Victor A. Dick, Major, USAF
Russell J. Down, II, Captain, USA
Thomas J. Fahey, Jr., Captain, USAF
Bernard J. Fine, Ph.D., Natick, Mass.
Sanford J. Freedman, Ph.D., Boston, Massachusetts
Henry D. Gallo, Captain, USA
Pedro Gavillan, M.D., Santurce, Puerto Rico
William Gillespie, M.D., St. Louis, Mo.
William M. Helvey, M.D., Farmingdale, L. I., New York
Richard H. Hood, Jr., Major USAF
Steven M. Horvath, Ph.D., Philadelphia, Pennsylvania
Kelvin D. Kable, Captain, USAF
Harold A. Lyons, M.D., Brooklyn, N. Y.
Norman H. Mackworth, Ph.D., Stamford, Connecticut
Jose A. Martinfz-O'Ferrall, Captain, USAF
J. A. McKinnon, Captain, USAF
David R. McMechan, Captain, USAF
John M. Mills, Captain, USAF
Hugh B. Mitchell, Major, USAF
Geo. C. Moench, Captain, USAF
Philip O'B. Montgomery, Jr., M.D., Dallas, Texas
Norman S. Namerow, M.D., Los Angeles, California
Richard G. Norenberg, Captain, USAF
Thomas F. Oehrlein, Baltimore, Maryland
Joseph B. Pomerance, M.D., Miami, Fla.
Donald J. Rosato, Captain, USA
Rolf G. Scherman, Captain, USAF
Prof. Bruno Schreiber, Parma, Italy
Philip G. Strauss, M.D., Burbank, Calif.
Chas. S. Thurston, Captain, USAF
Floyd W. Tingley, Captain, USAF
C. W. Waldrop, Jr., Captain, USAF
Takao Watanabe, 1st Lieutenant, J.A.F.
John Blair Webster, Lieutenant, USN
Roger H. L. Wilson, M.D., San Francisco, Calif.
Chris J. D. Zarafonetis, M.D., Philadelphia, Pa.

Special Announcement

An invitation is extended by the Scientific Program Committee of the

Aerospace Medical Association

to those interested in participating as speakers in the Scientific Sessions of the 32nd Annual Meeting to be held at the

PALMER HOUSE
Chicago, Illinois
April 24-27, 1961

All aspects of biological effects of aerial and space flight will be considered appropriate topics for presentation. The sessions will include:

Research and Education

Development, Testing and Operational Applications

Clinical Aerospace Medicine

Abstracts, including title, name of author(s), degree or rank, and laboratory or office, should be presented. Only the original copy of the abstract should be submitted, and it should not exceed one double-spaced typewritten page in length. Abstracts should be sent to Dr. John P. Marbarger, Director, Aeromedical Laboratory, University of Illinois, 840 South Wood Street, Chicago 12, Illinois, Chairman, Scientific Program Committee. Abstracts must be submitted prior to **December 1, 1960** for review by the Scientific Program Committee.

A résumé of the Scientific Program for the meeting will be published in the February issue, and abstracts of papers will be printed in the March issue of **Aerospace Medicine.**

The members of the Scientific Program Committee are:

E. J. Baldes, N. E. Baxter, P. A. Campbell, H. D. Estes, A. P. Gagge, J. D. Hardy, G. L. Hekhuis, A. W. Hetherington, E. B. Konecci, L. R. Krasno, A. M. Mayo, G. B. McNeely, D. G. M. Nelson, C. P. Phoebus, H. J. Schaefer, J. B. Stapp, W. K. Stewart, D. H. Stuhring, G. Douglas Talbott and C. S. White.

Aerospace Medicine

Abstracts of Current Literature

Prepared under the Direction of ARNOLD J. JACOBIUS, Ph.D.

History and General Aspects of Aviation and Space Medicine and Biology

562

Basic Research Efforts in Astrobiology. R. S. Young and J. L. Johnson. *IRE Trans. Military Electronics,* MIL-4 (2-3): 284-287, April-July 1960.

The special problems involved and some of the special devices which have been used to date in performing biologic experiments in space are described. Preliminary experiments in recoverable nose cones of Army ballistic missiles have been made in an effort to determine the effects of various flight parameters such as weightlessness, cosmic radiation, and increased gravity-load on cellular systems and intact organisms. Some of the experiments were simple, passive ones wherein biologic materials (yeasts, bacteria, molds, seeds, et cetera) flown in the nose cone were recovered and studied for radiation or other damage. Other experiments utilized the eggs and sperm of the sea urchin to study the effect of weightlessness on cell division and fertilization. The manner of packaging the materials and some of the problems which arose during the experiments are described in detail. No telemetric devices were used in these experiments. The need is cited for the development of instrumentation capable of accurately measuring and telemetering various physiologic responses of a wide variety of cellular systems subjected to accelerative forces, to conditions of vacuum, and to zero-gravity.

Aviation and Space Biology

563

The Exploration of Outer Space. A. C. B. Lovell. *Spaceflight* (London), 2 (7):194-203, July 1960.

The possibilities for the exploration of outer space have been increased by the development of techniques of earth-based radio astronomy, and through opportunities offered by space probes and satellites. In this paper, the author reviews and evaluates some of the information which has been obtained through these media and suggests lines of investigation which may be followed to extend our knowledge of outer space. Consideration is given to the limitations of the earth's physical environment, including the great radiation belt; to the dust particles and radiations of the interplanetary medium; to the distance, atmospheric constitution, and geophysical environment of the moon and the planets; to possibilities for extra-terrestrial life; to the cosmologic problems of time and space; and to radio-astronomic studies of the universe.

From the Bibliography Section, Science and Technology Division, Eugene Marrow, Ph.D., Editor of Abstracts, Library of Congress, Washington, D. C. Dr. Jacobius is senior editor of *Aviation Medicine: An Annotated Bibliography, Vol II (1953 Literature)*, a current publication of the Aerospace Medical Association.

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564

Some Results and Perspectives of Research in the Areas of Cosmic Biology. (Nekotorye itogi i perspektivy issledovanii v oblasti kosmicheskoi biologii). V. V. Parin, V. N. Chernigovskii, and V. I. Iazdovskii. *Izvestiia akademii nauk SSSR, Seria biologicheskaia,* 25 (1):3-18, Jan.-Feb. 1960. (In Russian, with English summary). German translation in: *Sowjetwissenschaft: Naturwissenschaftliche Beiträge* (Berlin), 1960 (7):677-689, July 1960.

The results of Soviet rocket experiments using live dogs are summarized. The first series explored the viability of animals enclosed in a hermetic cabin during a flight up to 100.8 km. altitude at a speed of 4212 km. The second series of investigations tested various escape possibilities with dogs in special suits but not enclosed in hermetic cabins. The dogs were catapulted from the rockets at 100 km. altitude at speeds of 700 to 725 m./seconds, and fell at 50 km. altitude at speeds of 1000 to 1150 m./seconds. The physical conditions of these animals remained within permissible physiologic limits throughout the flight. Other experiments similar to the above were carried out at higher altitudes. The second Sputnik experiment has proved conclusively that conditions equivalent to space flight are satisfactorily tolerated by higher animals. Problems still to be solved include selection procedures for astronauts. Problems of air regeneration, nutrition, water supply, and waste removal have been solved for short rocket flights.

565

Radiation Danger in Space. H. J. Schaefer. *Astronautics,* 5 (7):36, 42-45, July 1960.

A discussion is presented of the data recorded by a nuclear emulsion package recovered from the nose cone of a Thor-Able missile, which flew through the lower fringes of the Van Allen radiation belt. The significance of the data is evaluated by recapitulating the mechanism of proton attenuation in an absorbing medium and correlating this information with the penetration behavior of a pencil beam of monoenergetic protons in living tissue. The author expresses certain cautions to be observed in assessing the relative biologic effectiveness of the proton beam in the Van Allen belt and states that close attention must be paid, in particular, to the eyes of a human target, since the lenses of the eyes will be exposed to the full body entrance dose and will show a greater radiation sensitivity than the skin to permanent, progressing injury.

566

Would the Circumterrestrial Radiation Belts be a Mortal Danger for Our Future Astronauts? American, Russian, and French Experiences and Theories. (Les ceintures radiatives circumterrestres seraient-elles danger mortel pour nos futurs astronautes? Expériences et théories américaines, russes et françaises). S. Travers. *Fusées* (Paris), (14):155-162, Nov. 1959. (In French.)

A discussion of the nature of ionizing radiations surrounding the earth is presented as a conceptual foundation for the prediction of hazards to future astronauts. Subjects considered include the protective effect of the earth's atmosphere, the role of the earth's magnetic field in the formation of the Van Allen radiation belts, and the calculated spatial density and electric potential of ionizing particles. Assuming a 1 per cent rate of absorption of high energy particles by the body, maximum exposure is anticipated to be 0.01 roentgens per second, allowing an exposure time of less than one day. Maintenance of a manned space station is thus precluded unless it can be placed immediately above the atmosphere (400 km.) or between the radiation belts (5,000 km.). It is suggested that a hazard of importance equal to that of cosmic radiation may be produced by high altitude atomic explosions.

Aviation and Space Physiology (Exclusive of Neuro- and Sensory Physiology)

567

The Effect of Deep Hypothermia on the Carbohydrate-Phosphorus Metabolism of Brain Tissue. (Vliianie glubokoĭ gipotermii na uglevodno-fosfornyĭ obmen tkani mozga.) G. A. Nechaeva. *Biulleten' eksperimental'noĭ biologii i meditsiny* (Moskva), 48 (3) : 54-57, March 1960. (In Russian, with English summary.)

The level of inorganic phosphorus, adenosinetriphosphate, phosphocreatine, and lactic acid in cat's brain tissue remained unchanged during hypothermia as low as 14° C. This is indicative of the absence of hypoxia or any other condition which may disturb the equilibrium between glycolytic and oxidative processes. Even a brief interruption of the cerebral blood supply during hypothermia results in a disintegration of energy-producing substances. This fact should be considered while returning the animal to normal temperature levels. (Author's summary, modified.)

568

Modern Means for the Well-being of Man in Aviation and Space Flight, With Special Consideration of the Pressurized Cabin. (Moderni impianti per il benessere dell'uomo in navigazione aerea e spaziale, con particolari considerazioni sulle cabine pressurizzate.) A Palieri. *Rivista aeronautica* (Roma), 36 (5) : 749-768, May 1960. (In Italian.)

Following a summary of the principal physiologic effects of high altitude flight (anoxia, acapnia, aeroembolism, hearing and gastrointestinal disorders, hypoxia), a discussion is presented on the methods of providing man with a hygienic aircraft cabin atmosphere. These methods include an elaboration of systems for the regulation of cabin oxygen, humidity, and temperature; ventilation systems for the prevention of cabin stagnation or hyperoxygenation, and systems for pressurization and air purification. Cabin pressurization is described from the standpoint of design, equipment, maintenance and performance during both modern high altitude flight and future space flights.

569

Warmth, Glare and a Background of Quiet Speech: A Comparison of Their Effects on Performance. R. D. Pepler. *Ergonomics* (London), 3 (1) : 68-73, Jan. 1960.

In two experiments the effects of a high air temperature on the accuracy and manner of manual tracking were compared with those of quiet speech and of glare. In each experiment 12 subjects attempted to keep a pointer aligned with a moving target for 40 minutes in both a normal and a warm climate, with instructions to be as accurate as possible. During the middle 20 minutes of each period of work the subjects in one experiment faced the glare from a naked electric lamp, and those in the other had a quietly spoken narrative relayed to them. All three conditions reduced accuracy of alignment, but warmth affected the manner of tracking differently from quiet speech and glare. With the two latter conditions, movements of the pointer decreased in number, i.e., errors of alignment were corrected less frequently. At a high air temperature the number of movements of the pointer increased, i.e., corrections were more frequent than usual. It was concluded that glare and a background of quiet speech interfered with perception, but that warmth affected chiefly accuracy of movement. (Author's abstract.)

570

Biological Problems of Cosmic Flights. (Kosmiliste lendude bioloogilised probleemid.) R. Preem. *Eesti loodus* (Tallinn, Estonia), 1959 (6) : 330-338, Nov. 1959. (In Estonian.)

A review is presented of Russian achievements in the penetration of space, and of U.S. research on the medical aspects of acceleration and survival of supersonic bailout at low altitudes. Telemetered data from the dog, Laika, showed that the physiologic problems accompanying entry into space are not insurmountable. An alternative composition of the sealed cabin atmosphere involves substitution of helium for nitrogen, and an increase of oxygen concentration to 80 per cent. Such a replacement would allow the human organism to withstand greater changes in pressure for a longer period in case of a sudden break in the seal of the cabin. Environmental hazards such as cosmic radiation and meteors are discussed and evaluated as sources of danger to the space traveler. Different possible methods of returning an astronaut to earth are considered.

571

Work in Cold Environments: the Effect of Cold on Manual Performance. K. A. Provins and R. S. J. Clarke. *J. Occupational Med.,* 2 (4): 169-176, April 1960.

A review is presented of experimental studies of the effects of cold on reaction time, tracking proficiency, general dexterity, tactile discrimination, and muscle strength. Questions of correlation between performance on different tests of motor ability, of individual differences in susceptibility to impairment, and of the design of equipment for use in cold are briefly discussed.

572

The Effect of High Temperature in Combination With Physical Exertion on the Gastric and Pancreatic Secretion in Different Diets. (Vliianie vysokoĭ temperatury v sochetanii s fizicheskoĭ nagruzkoĭ na sekretornuiu funktsiiu zheludka i podzheludochnoĭ zhelezy pri razlichnykh rezhimakh pitaniia.) [M. I. Putilin] N. I. Putilin and [L. M. Staritska] L. N. Staritskaia. *Voprosy pitaniia* (Moskva), 18 (5): 24-30, Sept.-Oct. 1959. (In Russian, with English summary.)

Changes in the normal gastric and pancreatic secretory activity during physical stress and heat stress were studied in six dogs (four with isolated Pavlovian gastric pouches, two with pancreatic ducts ectropionized according to Pavlov). Physical and heat stress was imposed by having the dogs run on a treadmill with a load strapped on the back in 45° C. heat. The feeding times were varied with respect to the food given (bread, meat, or milk) and working times. Results show alterations in the normal secretory activities of the stomach and pancreas under the influence of physical stress in high environmental temperatures. The changes were most pronounced if the animals were fed immediately before or immediately after physical exertion. Feeding schedules of one hour before work or one hour after work resulted in less pronounced changes in secretory activity.

573

Work in Cold Environments: Nutritional Factors in Cold Acclimatization. K. Rodahl. *J. Occupational Med.,* 2 (4): 177-182, April 1960.

Observations of the mechanism of adaptation to cold environments in man are discussed in relation to experimental studies in animals of acclimatization to cold. It is suggested that the acclimatization of the Eskimo to cold is based chiefly on behavioral factors (clothing, activity level, shelter) rather than on the extreme physiologic changes (increased metabolism, thyroid activity, food intake) observed in rats exposed without protection to temperatures of 5° C. From consideration of studies of the nutritional habits and requirements of Eskimos and Europeans living in cold environments it is concluded that neither an increase nor a component change in nutritional requirements occurs in men living in cold environments.

574

The Phosphorus Fractions of Muscle During Hypoxia. (Fosfornye fraktsii myshts pri gipoksii.) I. G. Shcherbak. *Biulleten' eksperimental'noi biologii i meditsiny* (Moskva), 47 (6): 40-43, June 1959. (In Russian, with English summary.) English translation in: *Bull. Exper. Biol. Med.* (Consultants Bureau, New York), 47 (6): 693-695, June 1959.

Changes in the phosphorus fractions of skeletal muscle were studied in 42 normal rats and in 42 rats subjected for one hour to a lowered barometric pressure of 190 mm. Hg (corresponding to an altitude of approximately 10,000 meters). Biochemical examination showed a decrease in the content of creatinephosphate, acid-soluble phosphorus, and total phosphorus, no change in the concentration of preformed inorganic phosphorus, and a statistically unconfirmed increase in the lipoidal phosphorus content of excised thigh muscle of animals subjected to anoxia.

575

Vectorcardiography in Aerospace Flight: Applications and Rationale. George B. Smith and L. E. Lamb. *Am. J. Cardiol.*, 6 (1): 62-69, July 1960.

The vectorcardiogram offers three distinct advantages over the conventional electrocardiogram: (1) It enables relatively undistorted representation of the electrical forces of the heart; thus the true magnitude and direction of the spatial vectors are available. (2) The loop or spatial pathway described by the vectorcardiogram provides a measurement that is not available in the routine electrocardiogram; this may be plotted along a time base as in the linear vectorcardiogram. (3) The use of a cathode ray oscilloscope rather than a direct writing instrument allows greater accuracy in presentation of rapid or minute changes in electrical forces. Vectocardiography has an important application in assessing the pilot's cardiovascular system and in monitoring cardiovascular functions during flight. (From the authors' summary.)

576

Standardization of an Endpoint to Positive Acceleration on the Human Centrifuge. S. H. Steiner. Wright Air Development Center. Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Note No. 59-426, Dec. 1959. iii+8 p. (Project No. 7222, Task No. 71746). Unclassified.

In order to standardize the experimental variables in acceleration research among all of the different centrifuges, and thus make similar data comparable from one laboratory to another, studies have been made to establish an objective and standardized endpoint for positive acceleration experiments. A comparison was made of blackout thresholds to a red filtered light of 760 mμ, raised 0.5 log units above visual threshold in dark-adapted subjects and to a white light in the same subjects. A significant difference was found for each subject. Differences between white and red light varied from 1.1 to 2.8 g for this group. The differences observed would vary from one centrifuge to another depending on the intensity and transmission spectrum of the white light used. The physiologic implications, advantages, and possible sources for error are discussed. (From the author's abstract.)

577

The Effect of Changes in Posture and of Graded Exercise on Stroke Volume in Man. Y. Wang, R. J. Marshall and J. T. Shepherd. *J. Clinical Invest.*, 39 (7): 1051-1061, July 1960.

Cardiac output, heart rate, and stroke volume were measured in four healthy males at rest in the supine position, at rest standing, and during exercise in the upright position. Exercise varied from gentle movements of the calf muscles and marking time to walking at 4.5 m.p.h. up a treadmill inclined at 12 degrees from the horizontal. The cardiac index of subjects at rest in the supine position averaged 3.5 liters, and the stroke index averaged 54 ml. In the standing position, a fall in cardiac output (stroke index 32 ml.) and an increase in heart rate were observed. Moderate exercise restored the stroke index to the level obtained in the resting supine position; severe exercise increased the stroke index to 59 ml., with a cardiac output of 15-25 liters/min., and oxygen consumption of 2.0-2.8 liters/min. It is probable that the apparent discrepancies in previous reports of the stroke volume changes occurring during exercise were due to variations in the circumstances (supine or standing posture) under which resting values for stroke volume were obtained rather than to inadequate techniques for measuring cardiac output. (From the authors' summary.)

578

Ability and Performance on a Complex Perceptual-Motor Task. D. S. Abbey. *Perceptual and Motor Skills*, 11 (1) :55-56, Aug. 1960.

An analysis was made of the performance of four groups of subjects, differing in initial ability, on the standard task of the Toronto Complex Coordinator. Subjects were required to place a lighted green disc within a lighted red ring by the manipulation of an airplane-type control stick. Movement of the stick right, left, toward, and away from the display, moved the green light right, left, up, and down, respectively. When the disc was appropriately positioned for at least 0.33 seconds, another red light was illuminated and a match was recorded. The results showed that both the slope and the rate of change of the learning curve were related to the initial level of ability. Where early performance was low, rapid improvement was obtained. Where early ability was high, the learning curve was characterized by very small increments per trial. Improvement per trial (over a ten-minute practice period) was inversely related to the level of performance during the first minute.

579

Results of the Oxygen-Want Test and Their Relation to Unspecific Adaptation Processes of the Organism. H. Brüner, K. Dietmann, and K. E. Klein. *Deutsche Versuchsanstalt für Luftfahrt* (Mülheim, Germany), Report no. 125, p. 5-19, June 1960. (In English and German.)

A significant difference in the extent of eosinopenia occurring during hypoxia (7500 m.) was observed between subjects showing a rapid decrease in hypoxic efficiency reserve measured by the pellet-recorder test (type A) and subjects showing a more gradual decrease and greater total efficiency reserve (type B). Type B subjects showed a less marked decline in eosinophil level and a more rapid recovery after return to atmospheric pressure. It is suggested that the poorer functional efficiency reserve and apparently greater activation of the adrenal gland in type A subjects indicate a greater sensibility of the cells of the central nervous system to stress. It is concluded that with the assumption of cell hypoxia as the final effect of many stressors, the effectiveness of individual unspecific adaptation processes may be predicted from performance on the hypoxia test.

Neuro- and Sensory Physiology

580

Preliminary Study of Damping of the Otolith Organ System by Epicyclic Rotation. R. F. Gray and D. M. Morway. Aviation Medical Acceleration Lab., Johnsville, Pa. Report no. NADC-MA-5919, Dec. 28, 1959. ii+6 p. (Task no. MR 005. 13-6002.1, Report no. 10 (Formerly NM 17 01 12.1).) AD 231 600. Unclassified.

Damping characteristics of the otolith organ system in humans were studied by means of the oculogravic illusion. The oculogravic illusions were generated in four male subjects on the centrifuge by letting the direction of the resultant of centrifugal acceleration and gravity change in direction through the man so that his perceived vertical would change. The subject was then tumbled in the plane of rotation of the centrifuge around a true vertical axis to see if the effects of centrifugal acceleration could be eliminated, leaving only the effects of gravity, and thus reducing the apparent tilt of the oculogravic illusion by increasing the relative importance of the effect of gravity. It was concluded that tumbling does reduce the apparent tilt of the oculogravic illusion generated on the centrifuge, and could be effective in reducing the effect of gravity on the otolith organs.

581

Effect of Exposure to High Humidity at High and Moderate Ambient Temperature on Anagram Solution and Auditory Discrimination. B. J. Fine, A. Cohen, and B. Crist. *Psychol. Reports,* 7 (1):171-181, Aug. 1960.

Ten subjects were exposed for 6½-hour periods on four successive days to ambient dry/wet bulb temperatures of 70°/53° F., 70°/68° F., and 95°/92° F. with minimal wind. The four-day sequence was replicated four times during four successive weeks, the order of the conditions differing for each replication. Subjects performed an anagram and an auditory discrimination task immediately after entering and just prior to leaving the experimental situation. The intervening time was occupied by group performance of a mental task, the game of ghost. The results indicate that there was no increment or decrement in performance on either the anagram or auditory discrimination task that could be attributed to either high temperature or high humidity. (Authors' summary.)

582

Inner Ear and Spatial Disorientation of the Aircrew. (Laberinto auditivo y desorientación espacial de las tripulaciones). L. Iapalucci. *Argentina aerea* (Buenos Aires), 14 (169):10-11, Feb. 1960. (In Spanish.)

A brief discussion is presented of spatial disorientation of the aircrew caused by high speed accelerations and decelerations. The following suggestions for its prevention are presented: (1) complete inner ear and neuropsychiatric examinations and continued medical supervision of the crew members; (2) emphasis of the importance of relying on the instrument panel during the training period; (3) avoidance of flight under bad conditions of visibility, etc.; (4) detection of the conditions of chronic disturbances produced by tobacco, alcohol, fear, and neurovegetative dystonias (hyper- and hypotension, and tendencies towards migraine or allergy) which may affect the inner ear; and (5) consultation of flight surgeons familiar with the problems of vertigo and flight neuroses in investigations of aircraft accidents.

583

The Problem of the Role of Eye Movement During Vision. (K voprosu o roli dvizheniia glaz v protsesse zreniia.) A. L. Iarbus. *Biofizika* (Moskva), 4 (6):757-758, 1959. (In Russian.) English translation in: *Biophysics* (Pergamon Press, London), 4: (6);120-122, 1959.

In conditions in which the normal relation between movement of the eye and displacement of the retinal image was disturbed, visual assessment of proportions and distances became difficult but was not completely absent. All optical illusions were maintained and consequently their appearance cannot be ascribed to movement of the eyes. The tracking system of the eye in these conditions is unable to perform its functions. (Author's summary.)

584

Scientific Conference on the Problem of Space Perception and Illusions of Space, 20-23 May 1959. (Nauchnoe soveshchanie po probleme vospriiatiia prostranstva i prostranstvennykh predstavlenii). B. F. Lomov. *Voprosy psikhologii* (Moskva), 5 (6):182-186, Nov.-Dec. 1959 (In Russian.) English translation by U. S. Joint Publication Service, New York, No. 3405-D, May 19, 1960. (Available at Office of Technical Services, U. S. Dept. Commerce.)

This article summarizes briefly the reports presented at an interdisciplinary conference on the problems of space perception and spatial illusions organized by the Leningrad section of the Society of Psychologists of the Academy of Pedagogical Sciences. The seven reports at the first session dealt with the theoretic and physiologic role of the cerebral hemispheres in space perception, space-time relationship of stimuli in the activity of the visual analyzer, electroencephalographic indices of binocular and monocular vision, the functional configuration of the space analyzer, the relation of space perception to the development of reason, and the influence of language on space perception. The majority of the reports in the second session were devoted to the problem of participation and role of receptor movements, chiefly of the visual receptor. The third and fourth sessions covered problems of spatial illusions in children. Further reports discussed space perception and spatial illusions encountered in industry, sports, map reading, and flying.

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Attention to Individual Channels in a Bisensory Presentation N. E. Loveless. Univ. of Durham. Nuffield Department of Industrial Health, King's College, Newcastle-on-Tyne, England. Issued by Flying Personnel Research Committee (Gt. Brit.). Report no. FPRC Memo 129, Sept. 1959, 5 p. Unclassified.

An experiment was conducted to determine whether the initial difficulty encountered by subjects in earlier studies in using simultaneous visual and auditory presentation of signals lay in attending to both signal sources at once. The hypothesis was not supported; signal detection was found to be as efficient when subjects were forced to attend to both channels as when subjects used visual or auditory channels alone.

586

Experimental Examination of the Sensorimotor Reactions in the Process of the Medical Board Evaluation of Flight Personnel. (Eksperimental'noe issledovanie senso-motornykh reaktsiĭ v protsesse vrachebnoĭ ekspertizy letnogo sostava). B. L. Pokrovskiĭ. *Voenno-meditsinskiĭ zhurnal* (Moskva), 1959 (10):42-46, Oct. 1959. (In Russian.) English translation in: *Military Medical Journal,* 10:70-76. New York: U. S. Joint Pub. Research Service, No. 2102-N, Jan. 4, 1960. (Available at Office of Technical Services, U. S. Dept. Commerce.)

An experimental investigation of the simple reaction time and complex reaction time (modified IU. A. Petrov's method) was carried out in three groups of fliers, namely, (a) those with poor piloting technique but without pathology, and (b) those with nervous system disorders. The visual display, used for establishment of the complex reaction time, required learning the relationship between three colored lights and a set of keys which extinguished them and then relearning it after a change in the pattern. The healthy pilots were characterized by an average reaction time of less than 0.9 second, three or less errors, improvement in quality of work after the pattern change, and a uniform reaction time curve. An average reaction time exceeding 0.9 second, more than three errors, deteriorated work after change of the set, and wide fluctuations in reaction time are indicative of a nervous system disorder or poor psychologic suitability for flight.

587

A Technical and Professional Survey on "Perceptive Life" in Flight. (Una inchiesta technico-professionale sulla "vita percettiva" in volo). M. Strollo. *Rivista di medicina aeronautica e spaziale* (Roma), 23 (2):235-247, April-June 1960. (In Italian, with English summary.)

On the basis of Gemelli's theories concerning man in flight and the psychologic aspects of the man-machine system, a questionnaire was formulated for evaluating a pilot's perceptive abilities and orientation during flight and administered to a group of flight personnel. The results, tabulated in absolute values and percentages, indicate that the questionnaire is of value in analyzing the technical, professional and perceptive abilities of flight personnel and in placing them in a job for which they are most suited.

Aviation and Space Psychology

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Environmental Requirements of Sealed Cabins for Space and Orbital Flights: A Second Study. Part 3: Effects of Long Term Confinement on Personality and Perception. N. M. Burns and R. B. Ziegler. Naval Air Material Center. Air Crew Equipment Lab., Philadelphia, Pa. Report no. NAMC-ACEL-415, July 22, 1960. v+[60] p. (Project no. TED NAM AE-1403). Unclassified.

Six naval enlisted men served as subjects for eight days of confinement in a simulated space vehicle. The effects on personal perception, personality changes, and group interactions are described. The data obtained are compared with the pre-confinement observations in order to provide a detailed analysis of the personality and perceptual changes that can be anticipated in future long range space and orbital flights. An extensive review of the anecdotal and experimental literature is also provided. (Authors' abstract.)

589

Experimental Psychological Examination of Flight Personnel. (Eksperimental'nopsikhologicheskoe issledovanie letnogo sostava). F. D. Gorbov and L. D. Chaĭnova. *Voenno-meditsinskiĭ zhurnal* (Moskva), 1959 (10):36-41, Oct. 1959. (In Russian.) English translation in: *Military Medical Journal,* 10:60-69. New York: U. S. Joint Pub. Research Service, No. 2102-N, Jan. 4, 1960. (Available at Office of Technical Services, U. S. Dept. of Commerce.)

The use of the experimental psychologic examination as a part of the examination battery administered by the flight medical board is described. Briefly, the examination consists of having the subject solve numerical problems from a table, in which figures are of different colors. The final evaluation is based on the subject's behavior in the testing situation, correct and incorrect responses, his ideomotor responses, and reaction to interference. The test also employs a monitored multiple channel recording of physiologic indices (electroencephalogram, electrocardiogram, electromyogram, and electrodermal response). This examination is helpful in early diagnosis of incipient arteriosclerosis, sequelae of concussion, neuroses, chronic fatigue, and somatic asthenia. It is also used to reveal psychologic characteristics, which though not pathological, interfere with flight performance. Four such personality types, characterized chiefly by rigidity and perseveration, are distinguished.

590

A Study of the Individual Psychological Characteristics of Fliers and Medical Board Evaluation. (Izuchenie individual'nykh psikhologicheskikh osobennosteĭ letchikov i vrachebno-letnaia ekspertiza). V. M. Mishurin. *Voenno-meditsinskiĭ zhurnal* (Moskva), 1959 (10):46-48, Oct. 1959. (In Russian.) English translation in: *Military Medical Journal,* 10:77-81. New York: U. S. Joint Pub. Research Service, No. 2102-N, Jan. 4, 1960. (Available at Office of Technical Services, U. S. Dept. Commerce.)

A study of individual psychologic characteristics was conducted with three groups of fliers: (1) healthy but retarded in flight training, (2) neurotics and asthenics, and (3) healthy with good flight performance. A psychologic characterization was constructed for each flier after analysis of the following data: anamnesis, detailed analysis of reactions in flight, medical history, clinical examinations, and individual mental functions as determined by psychologic and physiologic methods, including an objective evaluation of the mobility and equilibrium of cortical processes (modified Ivanov-Smolenskiĭ method). Certain psychologic characteristics unfavorable to flight training were differentiated. These appeared generally in combination with certain negative characteristics of higher nervous activity, e.g. increased emotionality together with inertia of the cortical processes was the most frequent cause of poor assimilation of flight training.

591

Vigilance in Prolonged and Repeated Sessions. W. B. Webb and R. J. Wherry. *Perceptual and Motor Skills,* 10 (2):111-114, April 1960.

The responses of three subjects, monitoring an auditory aperiodic signal over five sessions of nine hours per session, were analyzed. The subjects were required to respond to small (10 c.p.s.) and large (20 c.p.s.) signal changes which varied up (210 c.p.s., 220 c.p.s.) or down (190 c.p.s., 180 c.p.s.) from a continuous base signal of 200 c.p.s. by pressing a designated telegraph key. Data were collected for errors (wrong key pressed), missed signals and latency of responses to each signal. A predictable change of monitoring behavior over the five sessions for all subjects was not obtained. One subject missed only six of the over 900 signals presented over the five days; another subject missed eight, and the third 19. These misses did not bunch in a given period and it is suggested that the use of two subjects monitoring such signals would result in extremely low probability of a signal being missed by both subjects. Within sessions, subjects showed an increasing latency of response. Two subjects showed an increase in variability of response and one a decrease in variability. The response latencies averaged 1.05 seconds for all subjects.

Aviation and Space Flight Personnel

592

Qualifying Aptitude Minimums as a Function of Recruiting and Training Objectives. L. D. Brokaw and F. E. Holdrege. Wright Air Development Division. Personnel Lab., Lackland Air Force Base, Texas. WADD Technical Note no. 60-134, May 1960. ii+5 p. (Project no. 7717, Task no. 87006). Unclassified.

This paper discusses the interrelationships between desired performance of technical training graduates, the length, content, and training standards of the course, and the aptitude qualification of the entrants into the training. The impact of shifting the cutting score upon the characteristics of the other factors in the production of airmen trained to the requisite level, is examined. The relationships between scores on selection or classification instruments and measures of proficiency, such as a final school grade, are described. (Authors' abstract.)

593

The Application of the U-Shaped Manometer Test for the Examination of Flight Personnel (O primenenii proby s U-obraznym manometrom pri osvidel'stvovanii letnogo sostava [Abstract]). V. E. Danilov. *Voenno-meditsinskii zhurnal* (Moskva), 1959 (9):83, Sept. 1959. (In Russian.) English translation in: *Military Medical Journal,* 9:143-144. New York: U. S. Joint Pub. Research Service, No. 2061-N, Dec. 28, 1959. (Available at Office of Technical Services, U. S. Dept. Commerce.)

The U-shaped mercurial manometer test is recommended in the selection of pilots for high altitude flights involving forced pressure oxygen breathing. Failure to maintain the mercury column at 60 mm. for 25 seconds or a syncope during the test should disqualify the individual for high altitude flight. This test may also be used in aeromedical board evaluations of individuals who display a tendency toward vascular collapse.

594

Factors Relating to Discharge for Unsuitability Among 1956 Airman Accessions to the Air Force. E. S. Flyer. Wright Air Development Center. Personnel Lab., Lackland Air Force Base, Tex. WADC Technical Note no. 59-201, Dec. 1959. iv+15 p. (Project no. 7719, Task no. 17155). Unclassified.

This report provides major findings from a large-scale research investigation in which suitable and unsuitable airmen were compared for a large number of personal attributes. Educational level was found to be the best single predictor of unsuitability discharge, although aptitude and age considered in conjunction with educational level significantly increased the accuracy of prediction. The implications of the findings for current selection procedures are discussed. (Author's abstract.)

595

Comparative Sociometric Observations Between a Group of Career Airmen and a Group of Enlisted Airmen (Osservazioni sociometriche comparative tra un gruppo di avieri di carrierà ed un gruppo di avieri di leva). G. Sabatelli, R. Onesti, and A. M. Regina. *Rivista di medicina aeronautica e spaziale* (Roma), 23 (2): 212-234, April-June 1960. (In Italian, with English summary.)

A sociometric test was given to a group of career airmen and a group of enlisted airmen in the Italian Air Force. Subjects were asked to select from their group the persons they preferred to work with on teams as well as those they did not wish to work with. A comparative analysis of the sociograms indicated: (1) a different social organization between the two groups; (2) that specialist non-commissioned career officers tended to select a group leader and displayed some interrelation among the subgroups (rejected airmen and those who grouped in pairs), and (3) that groups of enlisted specialists on temporary duty tended to discriminate against groups of newly recruited personnel and older airmen about to be discharged. These latter groups also formed social and work groups according to geographical area. The value of sociometric tests is noted for the study of the relationship between individuals, composition of groups, and for the formation of work teams.

596

The Psychological Selection Program of the German "Institut für Flugmedizin" (Aeromedicine). R. Seifert. *Deutsche Versuchsanstalt für Luftfahrt* (Mülheim, Germany), report no. 125, p. 53-63, June 1960. (In English and German.)

Preliminary data on the validity of the program of the German Institut für Flugmedizin for the selection of aircrews of the Deutsche Lufthansa indicate a test error rate of 6 to 12 per cent. Aptitude tests in use in the selection program include the complex coordination and link trainer tests of psychomotor performance, the *Institut's* own bend direction test of spatial relations, in which applicants are required to count bends in a square as quickly as possible, and the *Institut's* concentration-stress test, involving attention, memory span, visual alertness, and arithmetic.

597

Aeromedical Board Test in Initial Stages of Hypertensive Disease (Vrachebnaia ekspertiza letnogo sostava pri nachal'nykh formakh gipertonicheskoĭ bolezni). A. I. Severskiĭ. *Voenno-meditsinskiĭ zhurnal* (Moskva), 1959 (9):63-65, Sept. 1959. (In Russian.) English translation in: *Military Medical Journal,* 9:105-109. New York: U. S. Joint Pub. Research Service, No. 2061-N, Dec. 28, 1959. (Available at Office of Technical Services, U. S. Dept. Commerce.)

A group of 198 fliers suffering from incipient hypertension were tested in regard to fitness for further flight duty. All the subjects suffered from elevated blood pressure in combination with other cardiovascular and nervous symptoms. On the basis of this and other extensive studies of the initial stages of the hypertensive disease, fliers with blood pressures of 150/90 mm. Hg may be permitted to fly provided there are no subjective symptoms or objective organic or neuropsychiatric changes. Therapeutic-prophylactic measures for alleviating hypertension are described.

598

A Factor-Analytic Study of the USAF Officer Activity Inventory. L. D. Valentine. Wright Air Development Division. Personnel Lab., Lackland Air Force Base, Texas. WADD Technical Note no. 60-40, March 1960. iii+22 p. (Project no. 7719, Task no. 17108). Unclassified.

This analysis was designed to determine the actual number of distinct fields of interest that can be identified by an interest inventory scaled for 16 officer career fields. Two factor-analytic techniques were applied to the 16 job-interest scores from the USAF Officer Activity Inventory for a sample of new officers. The analyses each yielded five significant factors: Combat and Operations Interest, Administrative Interest, Technical Interest, Quantitative Interest, and Administrative (Personnel) Interest with corresponding factors defined by almost identical clusters of interest scales. In each analysis, one of the factors, Administrative (Personnel), was a subset of scales included in the broader Administrative factor. Thus, four distinct interest areas were defined, whose definition established their equivalence to the four interest measures included in the Air Force Officer Qualifying Test, and confirmed the judgment that four interest scales were adequate in the officer test battery. The factor analyses, presented in detail in the appendixes, are of special interest in showing how an incomplete hierarchical structure can be handled by the Schmid-Leiman hierarchical factor model. (Author's abstract.)

Operational and Human Engineering Aspects

599

Forced-Choice Ranking as a Method for Evaluating Psycho-physiological Feelings: One of a Series of Reports Pertaining to the Evaluation of Man's Minimum-Life-Space Requirements. P. S. Allen, E. M. Bennett, and D. K. Kemler. Tufts Univ. Department of Sociology. Bio-Mechanics Lab., Medford, Mass. (Contract AF 33(616)-3068); issued by Wright Air Development Center. Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Report no. 58-310, Dec. 1959. ix+123 p. (Project no. 7222, Task no. 71747). Unclassified.

Multiple forced-choice ranking methods were employed to assess comfort inducing or inhibiting characteristics of operational aircraft seats. The variety of new psychometric techniques used in this research proved efficient and comprehensive. The study involved judgment of subjective feelings based on the subject's selection of fixed numbers of stimuli from m, n from m-n, et cetera. The relevance of each stimulus was estimated by its place in the selection process. Two kinds of stimuli were judged: (1) descriptive terms selected by the subject to describe the sitting experience, and (2) portions of the posterior surface of the body (these were selected by the subject according to comfort level). In this way, the relative comfort profile of body parts was developed and compared with various seats and lengths of sitting time. The resulting profile patterns could be used in predicting success of seat design and suggesting design modifications. (Authors' abstract.)

600

Human Factors: Newest Engineering Discipline. C. Celent. *Electronic Industries,* 19 (2) :85-100, Feb. 1960.

Rapid technologic advances have generated problems concerning man-machine compatibility that call for an exhaustive knowledge of human behavior. These problems are especially critical in preparing for space travel, in that the man and the machine must be assigned the function each performs best. The space traveler must be protected against high or complex acceleration forces and weightlessness, and the effects of extremes of pressure, temperature, humidity, radiation, noise and vibration. Descriptions are given of various programs from industry, government, non-profit organizations, and private consulting firms which are attempting to solve these problems. Included are studies on the effect of motion and vibration on the ability of the pilot to control his craft; the development of telemetric devices for monitoring physiologic responses during space travel, and for lunar suit communications systems; the development of a satellite simulator to facilitate the design of living and working conditions in future extended-trip space vehicles; and the development of analog computers to simulate control situations in manned space vehicle re-entry.

601

Construction of Jet Aircraft (Konstruktsiia reaktivnykh samoletov). V. I. Fedorov. 266 p. Moskva: *Voennoe izdatel'stvo ministerstva oborony soiuza SSR, 1960.* (In Russian.)

Chapter VI deals with the following topics of interest to aviation medicine: (1) construction, equipment, and instrumentation of the cockpit, (2) medical care of the flier (problems of oxygen lack, lowered barometric pressure, and cold; (3) construction of sealed cabins (ventilation, air regeneration, air pressure regulation, and humidity and CO_2 control); (4) oxygen equipment (oxygen apparatus, oxygen masks, and oxygen pressure reducers); (5) diving and pressure suits; (6) escape devices (several types of ejection seats and capsules); and (7) anti-g suits.

602

Design Parameters for the Engineering of Closed Respiratory Systems. D. A. Keating. Wright Air Development Center. Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Report no. 59-766, Dec. 1959. Unclassified.

This paper contains a compilation of respiratory, environmental, toxicologic, and radiobiologic data considered to be pertinent physiologic knowledge for designers of such closed respiratory systems as are used in high-altitude or space vehicles. Tables show variations of barometric pressure and partial pressure of oxygen at various altitudes; the amounts of O_2, CO_2, N_2, and water vapor in inspired air (atmospheric) as compared with the amounts in alveolar air; the maximum tolerable concentrations (in parts of substance per million parts of ambient atmospheric air) of various toxic gases and vapors; the approximate comfort conditions (dry bulb-wet bulb temperatures and per cent relative humidity) of a clothed person in a "still air" environment; and permissible levels of radiation dosage for the whole body and critical organs, for the skin of the whole body, and for hands, forearms, feet, and ankles.

603

Moving Globe Displays Pilot Position. P. J. Klass. *Aviation Week,* 73 (2) :69-73, July 11, 1960.

Cockpit devices have been developed by Melpar and by International Business Machines Corp. to display vehicle position in true spherical coordinates on a small screen by projection from a transparent cartographic globe continuously positioned by signals from an external navigation computer. Small glass globes with the extreme cartographic detail and precision required for the device have been successfully produced by Melpar and by the USAF's Aeronautical Chart and Information Center.

604

Readying Crew Stations for Near-Space Aircraft. J. A. MacDonald. *SAE Jour.*, 68 (6):63-64, June 1960.

Improvements in personnel equipment and survival training have resulted in a decrease in escape casualties and an increased interest in flying high-speed aircraft. These improvements have come about through developments in human engineering, wherein man is the constant and machine designs are aimed to integrate and complement him rather than accommodate him. Automatic lap belts and shoulder harnesses with sensing devices which cause them to position the body so that maximum accelerations can be absorbed correctly, allow crew members to work in comfort and still have the full safety of restraining equipment. Advances in crew seat design have increased the g load tolerance for the occupant, and increased the crash load absorption capabilities of the seat. Future design of crew station components will adhere to established human engineering principles and closely follow today's configuration, because the operator's experiences require this similarity.

605

Pilot Aid Designed for Automatic Landing. J. Tunstall. *Aviation Week,* 73 (2):83-84, July 11, 1960.

A cockpit indicator positioned to present flight attitude information to the pilot's extrafoveal visual field during forward vision has been designed by Smiths Aircraft Instruments, Ltd. The display is composed of rotating cylinders painted in a black and white helical pattern which appears to move in the same direction as the required movement of the control column.

Pathology and Pharmacology of Aviation and Space Flight

606

Abnormalities of Thyroid Function in the Etiology of Vegetative-Vascular Disorders (Disfunktsiia shchitevidnoĭ zhelezy v etiologii sosudisto-vegetativnykh narushenii). V. P. Vavarin. *Voenno-meditsinskiĭ zhurnal* (Moskva), 1959 (9):66-68, Sept. 1959. (In Russian.) English translation in: *Military Medical Journal,* 9: 110-113. New York: U. S. Joint Pub. Research Service, No. 2061-N, Dec. 28, 1959. (Available at Office of Technical Services, U. S. Dept. Commerce.)

The possibility of abnormal thyroid function was investigated in 72 fliers with vegetative-vascular disorders between the ages 20-35 years. The absorption of radioactive iodine (I^{131}) by the thyroid was found to be normal in 50 individuals and elevated in 22 individuals with the most pronounced vegetative disturbances. Reexamination of 11 individuals after 8 to 12 months showed normal I^{131} absorption in seven, unchanged conditions in two, and increased absorption in two. The vascular-vegetative symptoms had improved correspondingly in the seven. The clinical picture in the two subjects with increased I^{131} absorption corresponded to moderate thyrotoxicosis with enlargement of the thyroid. It is concluded that abnormalities of thyroid function are present in approximately one-third of the cases of vascular-vegetative instability. Examination of the thyroid by the radioactive iodine method has been recommended to the aeromedical examination board in cases of vascular-vegetative instability.

Toxicology of Aviation and Space Flight

607

Fuel Poisoning with Special Reference to that Occurring in the Field of Aviation. (Le intossicazioni da carburanti con particolare riferimento a quelle che si verificano in campo aeronautico). G. Venditti and G. Lalli. *Rivista di medicina aeronautica e spaziale* (Roma), 23 (1):57-102, Jan.-March 1960. In Italian, with English summary.)

A discussion is presented on the nature, composition, and toxic effects of fuels with special emphasis on those used in aviation (gasoline, kerosene, fuel oil). The symptomatology, etio-pathogenesis, and pathology of gasoline poisoning of the pilot during flight and of the ground crew involved in aircraft maintenance is described and the manifestations of kerosene poisoning noted. The following protective measures are recommended for the ground crew: (1) selection of a well-aerated work environment; (2) medical selection and periodic examination of personnel in contact with toxic fuels (every 4 months for persons handling gasoline; every 6 months for those in contact with kerosene and derivatives); (3) collective hygienic education of personnel and instruction in the uses of personal protective equipment; and (4) use of drugs for prevention and therapy (vitamin B_{12}, B-complex, anti-anemic, vitamin C preparations). It is stressed that during flight personnel use oxygen masks at the first indication of gasoline fumes within the cockpit.

Preventive Medicine and Sanitation

608

Instrumentation to Monitor and Control Atmosphere Composition in Space Capsules. N. W. Hartz. In: Closed Circuit Respiratory Systems Symposium, p. 7-11. Wright Air Development Division. Life Support Systems Lab., Wright-Patterson Air Force Base, Ohio. WADD Technical Report no. 60-574, Aug. 1960. (Project no. 6373, Task no. 63120). Unclassified.

The working principles of four potential space capsule atmosphere analyzers are discussed. Devices utilizing infrared techniques could be selectively sensitized to measure carbon dioxide, water vapor, carbon monoxide, hydrocarbons, ammonia, and most of the fuels and oxidizers used for rocket power plants. Devices which use an alpha-excited ionization chamber (a Geiger tube used in reverse) may be sensitized for classes of compounds such as acid or alkaline contaminants, halogenated hydrocarbons or organo-metal compounds. Detectors containing sensing elements which respond to both thermal conductivity and thermal convection, combined with proper annulling resistors to produce selectivity, may be used in space vehicles to monitor CO_2 and hydrogen, as well as other components of the atmosphere. Devices based on the principle of catalytic oxidation may be used to detect relatively low concentrations of CO, hydrogen, hydrocarbons, ammonia, and HCN. These analyzers are commercially available, and, with proper modifications and size-scaling, offer a selection of instruments from which designers and operators may choose to fit a particular vehicle and its associated equipment.

609

Physico-Chemical Methods for Removing and Recovering Carbon Dioxide and Water Vapor from Exhaled Gases for Subsequent Reclamation of Oxygen from Carbon Dioxide. J. P. Hsu and A. B. Schwartz. In: Closed Circuit Respiratory Systems Symposium, p. 61-93. Wright Air Development Division. Life Support Systems Lab., Wright-Patterson Air Force Base, Ohio. WADD Technical Report no. 60-574, Aug. 1960. (Project no. 6373, Task no. 63120). Unclassified.

Several possible physico-chemical methods are described for removing and recovering carbon dioxide and water vapor from the cabin atmosphere for subsequent reclamation of oxygen from carbon dioxide. Methods of removing and recovering water vapor include (1) condensation by cooling or compression and cooling, and (2) adsorption followed by regeneration. Possible methods of removing and recovering carbon dioxide include (1) chemisorption by solution of alkanolamines followed by regeneration, (2) chemisorption by solution of alkali carbonates followed by regeneration, (3) absorption by water followed by rengeneration, (4) condensation by compression and cooling, (5) adsorption followed by regeneration, (6) reaction with metallic oxide followed by regeneration, (7) photosynthesis by green plants, and (8) artificial photo chemical reaction. Each method is evaluated, their advantages and disadvantages are discussed, and four overall processes based on combinations of these methods are set forth. It is concluded that, within the present scope of technical knowledge, absorption is probably the most feasible and practical process to remove and recover carbon dioxide from the space cabin air.

610

Regeneration of Oxygen from Carbon Dioxide in Closed Ecological Systems. W. Ruderman and L. Carr. In: Closed Circuit Respiratory Systems Symposium, p. 157-177. Wright Air Development Division. Life Support Systems Lab., Wright-Patterson Air Force Base, Ohio. WADD Technical Report no. 60-574, Aug. 1960. (Project no. 6373, Task no. 63120). Unclassified.

Two reduction cycles are described for regenerating oxygen from carbon dioxide in closed ecological systems. One, the Methoxy system, comprises the reduction of carbon dioxide with hydrogen to methane and water, and the subsequent decomposition of the methane to carbon and hydrogen. This hydrogen, along with the hydrogen from the electrolysis of the water, is recirculated to convert more carbon dioxide. A closed system results in which carbon dioxide is converted to carbon and oxygen. The other, the Electrocarb system, involves the decomposition of carbon dioxide at the cathode in an electrolytic cell containing a mixture of fused carbonates. The complete system results in the conversion of carbon dioxide to carbon and oxygen only.

Survival and Rescue

611

Development and Evaluation of Bio-Astronautic Life Support Systems. E. L. Hays and R. A. Bosee. In: *Life Support Systems for Space Vehicles,* Article 4, 12 p. Institute of Aeronautical Sciences, New York. Sherman M. Fairchild Publication Fund Paper No. FF-25, 1960.

Consideration is given to certain problems of space and orbital manned flight systems as they are related to full-pressure suit systems and specific types of closed-circuit respiration and environmental control equipment. The developmental histories of the equipment are reviewed. A brief discussion is given of the facilities now available for investigations in bio-astronautics.

612

Thoughts on Air Evacuation of Casualties (Réflexions concernant le transport primaire des blessés par voie aérienne). J. L. Binet. *Revue des Corps de santé des armées* (Paris), 1 (3) :413-421, June 1960. (In French.)

Medical aspects of the introduction of medium and heavy helicopters for evacuation of casualties from battle sites to centers of initial medical treatment are discussed. It is suggested that the advantages afforded by medical care en route and by reduction of transportation time support the advisability of air evacuation from a medical viewpoint. Various methods of traumatic shock treatment necessitated by the conditions of flight are discussed, including venous catheterization, the use of plastic infusion containers, and the determination of blood pressure by an apparatus (such as Yacoël's) which is unaffected by noise and vibration.

613

Development of Techniques for the Evaluation of High Altitude Pressure Suits. R. Contini, R. Drillis, and L. Slote. New York Univ. College of Engineering. (Contract AF 33(616)-3592); issued by Wright Air Development Center, Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Report no. 58-641, Dec. 1959. ix+121 p. (Project no. 6333, Task no. 71516). Unclassified.

A study was made to develop objective criteria to facilitate the selection of that pressure suit or component which permits the operator maximum function, and to make available to the manufacturer of the suit or component objective data from which improvements may be made in the design of the item. To accomplish these purposes, the techniques and methodologies associated with biomechanics were studied for their application to pressure-suited personnel. Psychologic and physiologic techniques were investigated for usefulness in the over-all investigation. During the course of this study only the basic movements of the upper extremities were considered. Nonetheless, the methods can be applied generally to other body segments, and, therefore, an over-all evaluation of a pressure suit or suit component can be accomplished. (From the authors' abstract.)

614

Design Study of High Pressure Oxygen Vessels. D. A. Keating. Wright Air Development Division. Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Report no. 59-767, Feb. 1960. iv+23 p. (Project no. 6373, Task no. 63120). Unclassified.

The theoretical feasibility of storing gaseous breathing oxygen under extreme high pressures for life support in flight operations was investigated by analytic and graphic technique. Optimum internal pressure was determined from the minimum mathematical product of vessel weight and volume and from evaluation of the strength characteristics of the vessel material. High pressure oxygen storage vessels utilizing an internal pressure at approximately 7500 p.s.i.a. were found for missions of moderate duration to be theoretically superior on a weight-volume basis to standard liquid oxygen converters. (Quoted in part.)

615

Nutrition in Space. L. M. Hursh. *Military Med.,* 125 (8) :567-569, Aug. 1960.

The nutritional and respiratory-ventilatory requirements for man on speculative trips into space (a 1-hour trip from Washington, D. C. to Peking, China, a 1-week round-trip to the moon, and a 1-year tour of duty on the moon) are discussed. The application of current knowledge on the chemical removal of carbon dioxide and carbon monoxide from the atmosphere, and of the packaging and storing of oxygen, water, and food will suffice for a 1-week trip to the moon and back. Enough food for a 1-year tour cannot be carried, however, and the utilization of unicellular organisms for this purpose is indicated. Current research on the use of algae for food and as closed-circuit gas exchangers is reviewed. Mention is also made of hydroponic research using volcanic ash, feces, and urine, and of experiments with rapidly growing animals such as rabbits and chickens which can use algae as food.

616

High Altitude Chambers and Pressure Suits and Their Part in Manned Flight to the Moon. E. W. Still. *Jour. Brit. Interplanetary Soc.* (London), 17 (8) :239-276, March-April 1960.

A discussion is presented of the environmental system engineering needed to sustain man during all phases of a journey to the moon and back. Current and proposed projects of the space program such as Manhigh, X-15, Mercury, DynaSoar, and the Lockheed Space Station, are reviewed. The information from these projects is then used to estimate parameters such as size of cabin, number of crew, duration of flight, and possible heat loads for all stages of such a journey. A description is given of the minimum requirements of food, water, and oxygen, the desired temperature, and tolerable levels of toxic substances (odors, carbon monoxide, ammonia). A proposed re-entry vehicle, a large space station, and a lunar suit are described in detail. Emergency situations (escape during take-off or re-entry, fire hazard in the space vehicle, and survival when alighting on water) and their counter measures are considered. It is concluded that the environmental engineering for a manned trip to the moon represents no insurmountable extension of existing knowledge, but if voyages are projected to Mars or other planets, considerable development of closed-circuit ecology is needed.

ANNOUNCEMENT

Career Opportunities

The Association frequently has requests from various sources for information on employment in the field of aerospace medicine. Beginning in January, a new section of THE JOURNAL will attempt to meet these needs and requests. In order to make this service effective, it is necessary to solicit information from all sources, including the names of both applicants seeking information concerning employment and the aerospace industries, corporations and government agencies requiring specialized personnel. We shall need names of both applicants and employers. This new section of THE JOURNAL will list positions available and positions wanted.

Members, Corporate Members, Subscribers and all interested parties requiring and seeking future career opportunities are requested to contact the Office of the Managing Editor, Dr. William J. Kennard, Washington National Airport, Washington 1, D. C.

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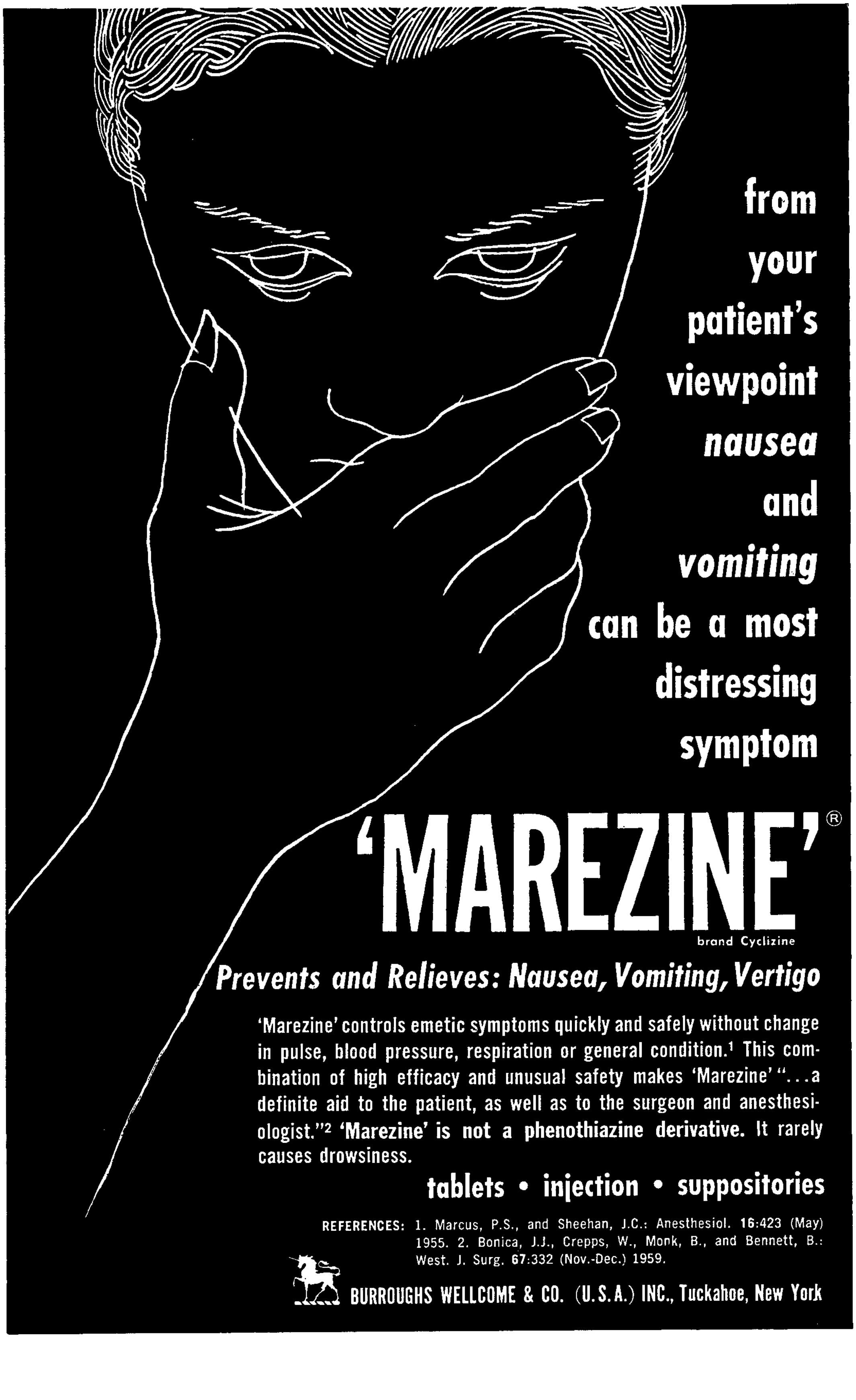
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